



## Impact of Active Transportation on Reducing or Avoiding Vehicle Miles Traveled and Greenhouse Gas Emissions

*Requested by*  
Darwin Moosavi, Division of Transportation Planning

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# Executive Summary

## **Background**

The Transportation Research Roundup Group includes representatives from four California agencies: Caltrans, the California Energy Commission, the Air Resources Board and the Department of Housing and Community Development. This group is interested in learning about the effects of active transportation (a means of getting around that is powered by human energy, primarily walking and bicycling; sometimes referred to as “nonmotorized transportation”) on the avoidance or reduction of vehicle miles traveled (VMT) and greenhouse gas (GHG) emissions. The results of this information-gathering effort can be used to provide support for the funding of active transportation projects.

To support this effort, CTC & Associates examined published and in-process research and other relevant publications related to active transportation in the following topic areas:

- Tools, models and other practices that quantify the impact of active transportation on GHG and VMT avoidance or reduction in both rural and urban active transportation projects.
- Metrics that allow a transportation agency to associate a specific active transportation project with an expected impact on GHG and VMT.
- Policies, strategies and characteristics of the built environment that encourage the use of active transportation.

To supplement the results of this literature review, we contacted representatives from selected transportation agencies expected to have experience with quantifying the impact of active transportation projects on VMT and GHG.

## **Summary of Findings**

### **Models and Tools**

#### General Guidance

The literature search uncovered limited general guidance associated with models or tools to estimate the impacts of active transportation on VMT and GHG emissions. Some of that guidance indicates that the models and tools are evolving and require further development. For example, a 2014 NCHRP guidebook includes profiles of models used to address bicycle and pedestrian travel behavior and demand. Of those models that permit analysis at the project/site level, none include a metric for VMT. A Safe Routes to School National Partnership publication also examines the pros and cons of modeling strategies.

The model developed for the Nonmotorized Transportation Pilot Program, which supplied funding to four pilot communities to construct nonmotorized facilities, provided “an innovative approach to estimating averted VMT and changes in walking and bicycling mode share” using location counts and data from the National Household Travel Survey. While focused on estimating the public health benefits of active transportation at a regional level, the Integrated Transport and Health Impacts Model (I-THIM) also estimates reductions in GHG emissions associated with higher levels of active transportation.

While not describing a specific tool, a January 2015 journal article highlighted the need for better data, in this case better estimates of the “substitution effect”—determining the degree to which walking and bicycling substitutes for car driving. Researchers note that better estimates of the substitution effect will lead to better estimates of the environmental impacts of bicycling and walking.

### Agency Practices

Methodologies used at the agency level to assess the environmental impacts of active transportation appear to be more likely than other models or tools highlighted in this Preliminary Investigation to allow for a project-level analysis.

Excel-based calculators are used by three agencies to assess emissions associated with active transportation:

- A benefits calculator developed by Florida DOT converts predicted bicycling trips into corresponding energy, health and carbon dioxide (CO<sub>2</sub>) emissions benefits and allows for a comparison of alternative projects.
- The CMAQ Calculator developed by Atlanta Regional Commission makes assumptions about new bicycle or pedestrian facilities drawing some automobile VMT away to biking or walking modes of travel and calculates emission differences as a result.
- Tahoe Regional Planning Agency uses a bicycle and pedestrian use model to examine the overall change in VMT associated with the region’s shared-use path facilities.

Projects in the Pacific Northwest examined the effects of improvements to a bicycle/pedestrian network by quantitatively defining and calculating the environmental impacts of a project at the sketch-planning stage, and related sidewalk availability with VMT and GHG emissions.

A report produced for Vermont Agency of Transportation highlighted the challenges faced by agencies attempting to quantify how increased walking and biking translates to transportation system cost savings, which include reductions in VMT and GHG emissions.

### International Practices

In Ireland, researchers used census data to estimate the benefits of a modal shift from driving alone to walking, cycling and carpooling. The COPERT IV model was used to estimate the associated reductions in CO<sub>2</sub> emissions. In the first of two Canadian studies, researchers evaluated built-environment influences on GHG emissions resulting from different land use and transportation policies. A second study described the Municipal Transportation and Greenhouse Gas model, which evaluates five strategies—land use intensification, public transport, active transport, financial policies and vehicle technology—to estimate transportation emissions, run forecasting scenarios and identify responses to policies.

## **The Built Environment and Active Transportation**

This is an expansive area of research, and we sought to provide a sampling of the more recent resources available. Several publications provide models for anticipating changes in pedestrian and bicyclist behavior or estimating the magnitude of change in active transportation when associated with specific policies or land uses, while others examine the features of the built environment that most strongly correlate to increases in walking or bicycling. A conference paper used detailed travel data from the Seattle metropolitan area to evaluate the effects of

built-environment variables on the use of biking and walking, and a TCRP report looked at the traveler response to active transportation facilities along with the effects of associated programs and promotion. The UrbanFootprint scenario planning model includes a public health module with metrics for physical activity-related weight and disease incidences, pedestrian safety measures and respiratory impacts. The SMARTRAQ study in Georgia identified tangible benefits associated with a walkable built environment, including decreases in air pollution and increased levels of physical activity.

## **Gaps in Findings**

While the literature related to active transportation is abundant, we uncovered little research examining the impact of individual active transportation projects on VMT and GHG emissions. We found evidence that the tools used to make such estimates are evolving, and further work is needed to refine and advance data-collection efforts and the models and tools themselves. We also did not uncover specific metrics used to assess individual active transportation projects. Contacts to regional planning agencies netted the most useful information, including examples of tools used to assess site-specific impacts. Additional contacts to similar agencies may generate other useful information.

## **Next Steps**

Moving forward, Caltrans could consider:

- Consulting with agencies using Excel-based tools to assess active transportation projects (Florida DOT, Atlanta Regional Commission and Tahoe Regional Planning Agency).
- Contacting additional state and regional transportation agencies to inquire about the use of models and tools to quantify the impact of active transportation on VMT and GHG emissions.
- Reviewing the models profiled in NCHRP Report 770 and in other publications cited in this Preliminary Investigation to identify potential areas of interest to Caltrans.
- Following up with Lawrence Frank, the principal investigator for the April 2011 Washington State DOT study that related sidewalk availability with VMT and GHG emissions, to learn about possible further developments of this area of research or related areas of inquiry.

## Detailed Findings

### Models and Tools

The citations in this section are organized in three categories:

- General Guidance.
- Agency Practices.
- International Practices.

#### General Guidance

Many of the publications highlighted below address the need for additional research or further development of models and tools, as well as data-collection efforts, to more accurately assess the environmental and other impacts of active transportation. Challenges associated with project-level analysis are also highlighted.

**“Accounting for the Short Term Substitution Effects of Walking and Cycling in Sustainable Transportation,”** Daniel P. Piatkowski, Kevin J. Krizek and Susan L. Handy, *Travel Behaviour and Society*, Vol. 2, No. 1, pages 32-41, January 2015.

Citation at <http://dx.doi.org/10.1016/j.tbs.2014.07.004>

From the abstract:

The environmental benefits of bicycling and walking depend on the degree to which their use substitutes for car driving. Assuming that every walking and bicycling trip replaces a driving trip is likely to produce overestimates of the potential for such modes to reduce vehicle travel and city-scale greenhouse gas emissions. Measuring this “substitution effect” is not straightforward. There are many dimensions of the substitution effect, including trip type, substituting mode, extent, time horizon, and activity patterns. Previously used approaches to measure substitution include indirect inference and direct questioning. This study piloted an intercept survey using the direct questioning approach at five locations in two metropolitan areas. The rate at which utilitarian walking or cycling trips substituted for auto trips ranged between 25% and 86%. Logistic regression models demonstrate that disparate factors explain walking substitution and bicycling substitution behavior; age is significantly correlated with substitutive walking behavior while number of car trips per week and helmet use are each significant predictors of bicycle substitution. This research represents a valuable first step toward developing a method to estimate the substitution effect that is useful for practitioners. Better estimates of the substitution effect will in turn lead to better estimates of the environmental impacts of bicycling and walking.

**Estimating Bicycling and Walking for Planning and Project Development: A Guidebook,** J. Richard Kuzmyak, Jerry Walters, Mark Bradley and Kara M. Kockelman, NCHRP Report 770, 2014.

[http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp\\_rpt\\_770.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_770.pdf)

Chapter 5, Application of Methods, which begins on page 59 of the report (page 68 of the PDF), is considered the core of this recently published guidebook. The authors note that “[u]ntil universal tools become available, the collection of tools in this guidebook offer a credible means

to address a wide range of planning questions related to bicycle and pedestrian travel behavior and demand.”

A review of the model profiles that appear later in Chapter 5 indicates that of those models capable of evaluating at the project/site level, none include a metric for VMT. The models that do include VMT as an output metric or performance measure generated by the model to support planning applications include:

- *Tour-generation and mode-choice models.* These tools use a highly disaggregated modeling approach—individual tour generation and mode choice at the parcel level—to account for the many factors that affect bicycle and pedestrian travel choice, particularly land use and network connectivity through measures of both local and regional accessibility.
- *Seattle enhancements to trip-based model.* This approach illustrates how sensitivity in traditional trip-based models can be enhanced by introduction of land use and accessibility measures at the auto ownership, trip generation and mode split steps.

**Improving Modeling and Data Collection for Active Transportation**, Safe Routes to School National Partnership, May 2014.

[https://saferoutescalifornia.files.wordpress.com/2014/05/data-collection-and-modeling-for-active-transportation\\_final\\_5-13-14.pdf](https://saferoutescalifornia.files.wordpress.com/2014/05/data-collection-and-modeling-for-active-transportation_final_5-13-14.pdf)

This report addresses in some detail the pros and cons of four modeling strategies—four-step, activity-based, scenario planning and public health models—that incorporate active transportation.

Below is an excerpt from a summary that begins on page 11 of the report, focusing on the recommendations for each model type to more effectively address the impacts of active transportation:

- *Traditional Four Step Models.* Many Four Step Models are still being used by [metropolitan planning organizations] because newer models are still being calibrated and have not yet been extensively used to produce data for environmental impact reports. Agencies are therefore reluctant to discontinue their use. We recommend that these models continue to be used until agencies are comfortable with the ability of newer [Activity Based Models (ABMs)] to estimate statutory requirements. However, we recommend that their use for making policy decisions should be contextualized and limited and that other models that better represent all trips be used to inform these discussions.
- *Activity Based Models.* In order for ABMs to accurately represent the benefits of active transportation and the impact of specific transportation investments, additional investments need to be made to collect active transportation trip behavior from a variety of projects. We recommend that MPOs invest in additional data collection efforts and continue to fund improvements to ABMs to ensure that they can accurately predict travel behavior for active transportation trips.
- *Scenario Planning Models.* Additional investments need to be made to ensure that accurate results can be gleaned from these models. In addition, since these models rely on the data from ABMs to produce results, additional data on active transportation trips needs to be provided, especially at the project level of analysis.

- *Public Health Models.* These models need to be further developed and expanded to more regions so that statewide benefits can be calculated. This will help state level policy makers make important decisions related to Active Transportation funding.

The report also includes a discussion of the project-level models of interest to Caltrans. From page 13 of the report:

- *Project Level Models.* Cities and counties rely on project level models to generate trip estimates for new transportation projects. Applications for state and federal funding often rely on these estimates to develop cost and benefit analysis for project eligibility. Project level models for active transportation have been developed by numerous consulting firms and public agencies. Unfortunately, many of these are sketch type models that give only rough estimates for a project's expected trip generation.

**PROS:** Project level models are necessary to justify investments in specific projects. They can be used to analyze different facility types to determine the most cost effective strategies for specific project locations.

**CONS:** There are no widely recognized models currently in use that local agencies can use to develop project level estimates for trip generation rates. This makes applying for state and federal funding onerous and time consuming.

**RECOMMENDATIONS:** MPOs and state agencies should develop and adopt standardized tools for calculating the active transportation trip rates that different infrastructure investments will generate in different land use scenarios. In addition, additions for safety and greenhouse gas reductions should be included.

**Report to the U.S. Congress on the Outcomes of the Nonmotorized Transportation Pilot Program**, SAFETEA-LU Section 1807, Federal Highway Administration, April 2012.

[http://www.fhwa.dot.gov/environment/bicycle\\_pedestrian/ntpp/2012\\_report/final\\_report\\_april\\_2012.pdf](http://www.fhwa.dot.gov/environment/bicycle_pedestrian/ntpp/2012_report/final_report_april_2012.pdf)

The Nonmotorized Transportation Pilot Program (NTPP) provided funding to four pilot communities "to construct ... a network of nonmotorized transportation infrastructure facilities, including sidewalks, bicycle lanes, and pedestrian and bicycle trails, that connect directly with transit stations, schools, residences, businesses, recreation areas, and other community activity centers." Among the lessons learned (beginning on page 85 of the report, page 91 of the PDF):

- While NTPP focuses mainly on bicycle and pedestrian facilities, strong education, outreach, and marketing programs are needed to complement the capital facilities. All of the communities engaged in outreach and educational activities; particularly notable examples include road safety classes for adults and youth in many communities, as well as training for local law enforcement and engineers in Columbia, Missouri, and Sheboygan, Wisconsin.
- The NTPP model represents an innovative approach to estimating averted VMT and changes in walking and bicycling mode share, using location counts and data from the [National Household Travel Survey]. This relatively inexpensive approach offers the opportunity to make reasonable estimates of changes on a community wide basis, assuming that the count data are of high quality. While using national survey data allows the model to make consistent assumptions across all four communities, future evaluation efforts would benefit from more localized household survey data. One goal for future evaluations may be to include travel diaries or questions about nonmotorized transportation behavior in routine regional household travel surveys.

*Related Resource:*

**“Estimating the Impacts of Nonmotorized Transportation Pilot Program: Developing a New Community-Wide Assessment Method,”** Benjamin Rasmussen, Gabe Rousseau and William M. Lyons, *TRB 92nd Annual Meeting Compendium of Papers*, Paper #13-4916, 2013.

<http://docs.trb.org/prp/13-4916.pdf>

The spreadsheet-based model developed for the NTPP uses communitywide annual count data to calculate mode share and VMT avoided due to nonmotorized travel for the years 2007 and 2011. An excerpt from the abstract:

Bookend counts in each of the communities estimate that between 2007 and 2011, bicycling and walking increased 67 percent and 32 percent respectively in the pilot communities. Based on these counts, the model estimates that between 2007 and 2011, people walked or bicycled nearly 75 million miles instead of driving, saving over 3.3 million gallons of gas. This number of avoided vehicle miles traveled reflects new bicycling and walking trips added to the levels assumed for 2007 and controls for population growth from 2007 to 2011. This finding supports one of the underpinnings of the NTPP program: that by improving nonmotorized transportation networks, more people will choose to walk and bike for transportation.

**Health Co-Benefits and Transportation-Related Reductions in Greenhouse Gas Emissions in the Bay Area: Technical Report,** Neil Maizlish, James Woodcock, Sean Co, Bart Ostro, Amir Fanai and David Fairley, California Department of Public Health, November 2011.

[https://www.cdph.ca.gov/programs/CCDPHP/Documents/ITHIM\\_Technical\\_Report11-21-11.pdf](https://www.cdph.ca.gov/programs/CCDPHP/Documents/ITHIM_Technical_Report11-21-11.pdf)

While focused on estimating the public health benefits of active transportation at a regional level, the Integrated Transport and Health Impacts Model (I-THIM) described in this report also estimates reductions in GHG emissions that are associated with higher levels of active transportation. (I-THIM is also addressed in an April 2014 Caltrans report cited on page 16 of this Preliminary Investigation.)

Excerpts from the executive summary:

A public health research team recently developed the Integrated Transport and Health Impacts Model (I-THIM) that makes it possible to estimate the health co-benefits and potential harms from active transport and low carbon driving in urban populations. The California Department of Public Health partnered with the developers of I-THIM, the Metropolitan Transportation Commission, and the Bay Area Air Quality Management District to apply this model to possible scenarios of active transport and low carbon driving that could unfold in the nine county San Francisco Bay Area by 2035.

....

The health impacts model was applied to a range of active transport scenarios that from a 2% baseline would attain a combined walking and bicycling mode share of up to 15% of travel distance. This corresponds to an increase in an average person's (median) weekly walking and bicycling from 31 minutes to 154 minutes.

....

Almost all (99%) of the health benefit arises from increased physical activity rather than from less air pollution. While low carbon driving generated little health co-benefits, it is estimated to reduce GHG emissions 9% to 33.5% from the 2000 baseline. The most ambitious active transport scenario would achieve from 9% to 14.5% in GHG reductions.

## **Agency Practices**

The publications below describe models or tools used to calculate VMT or emissions benefits (Florida, Georgia, Nevada and Oregon); the challenges associated with calculating the impact of walking and biking (Oregon and Vermont); and the effect of sidewalk infrastructure on VMT and GHG emissions (Washington).

### **Florida**

**Conserve by Bicycle Phase 2 Study**, State Safety Office, Florida Department of Transportation, 2015.

<http://www.dot.state.fl.us/safety/4-Reports/Bike-Ped-Reports.shtm>

This web page provides links to various elements of this research study aimed at “quantifying the benefits of bicycling and bicycling encouragement,” including a link to a benefits calculator. Models developed for this study are used to predict corridor-level bicycling and walking use.

The second phase of this two-phase project involved enhancing a worksheet-based tool to calculate energy savings and health benefits associated with the predicted number of recreational and utilitarian bicycle and pedestrian trips for a roadway corridor. In Phase II, researchers incorporated the latest recreational and utilitarian models and calculations for CO<sub>2</sub> emissions reductions.

#### *Related Resources:*

**Benefits Calculator**, Conserve by Bicycling and Walking Phase II, Florida Department of Transportation, undated.

<http://www.dot.state.fl.us/safety/4-Reports/Bike-Ped/CBBPhase2benefits%20calculator.xlsx>

This Excel-based benefits calculator converts “the predicted trips into corresponding energy, health and (at the request of Steering Committee members) CO<sub>2</sub> emissions benefits,” allowing for a comparison of alternative projects.

**Appendices**, Conserve by Bicycling and Walking Phase II Report, Florida Department of Transportation, October 2009.

[http://www.dot.state.fl.us/safety/4-Reports/Bike-Ped/CBBPhase%202%20final%20report\\_appendices.pdf](http://www.dot.state.fl.us/safety/4-Reports/Bike-Ped/CBBPhase%202%20final%20report_appendices.pdf)

The Bicycle and Pedestrian Facility Benefits Calculator: User Guide begins on page 7 of the document.

### **Georgia**

**Congestion Mitigation and Air Quality**, Atlanta Regional Commission, 2014.

<http://www.atlantaregional.com/environment/air/cmaq-calculator>

This web site includes a link to the Atlanta Regional Commission (ARC) CMAQ Calculator and a user guide for the tool. Among the project types considered by the tool are bicycle and pedestrian projects. The tool makes assumptions about new facilities drawing some automobile VMT away to biking or walking modes of travel and calculates emission differences as a result. From the web site:

In an effort to help standardize best practice in evaluating Congestion Mitigation and Air Quality Improvement (CMAQ) projects, the ARC contracted work to develop a modular CMAQ emissions calculator. The tool highlights changes in NO<sub>x</sub>, VOC, PM<sub>2.5</sub>, and

greenhouse gas emissions and, where applicable, vehicle hours of delay and vehicle miles travelled.

The tool calculates benefits for 16 types of strategies including, but not limited to: transit enhancements, system operations strategies, alternative fuels, demand management strategies, and bicycle and pedestrian investments. The calculator is currently calibrated only for the Atlanta region, but can be customized and adopted for other regions throughout the country.

#### *Related Resources:*

**ARC CMAQ Calculator v2**, Atlanta Regional Commission, undated.

[http://www.atlantaregional.com/File%20Library/Environment/Air/ARC\\_AQCal\\_Version2\\_20150109.xlsx](http://www.atlantaregional.com/File%20Library/Environment/Air/ARC_AQCal_Version2_20150109.xlsx)

ARC's Excel-based spreadsheet is used to identify changes in GHG emissions and VMT associated with bicycle and pedestrian projects.

**Emissions Calculator Technical Documentation and User Guide**, Atlanta Regional Commission, August 2014.

<http://www.atlantaregional.com/File%20Library/Environment/Air/ARC-CMAQ-Calculator-Documentation.pdf>

A discussion of bike and pedestrian projects is provided on page 45 of the PDF. From the guide:

This approach evaluates bike and pedestrian infrastructure improvements that are parallel to an arterial roadway with known average daily traffic (ADT) volumes. The benefits of increased transit ridership are included for bike and pedestrian projects that provide increased accessibility to transit. Projects can be evaluated individually for bike or pedestrian facilities, or combined.

Pedestrian and bicycle facilities can reduce emissions when auto trips are replaced by walking, biking, and transit trips. The methodology estimates the annual number of vehicle trips reduced, and the annual auto VMT reduced to approximate the emissions reduction.

## **Nevada**

**Environmental, Economic and Public Health Impacts of Shared Use Paths in Lake Tahoe**, Tahoe Regional Planning Agency, December 2009.

[http://www.tahoempo.org/documents/Impacts\\_Memorandum\\_110107.pdf](http://www.tahoempo.org/documents/Impacts_Memorandum_110107.pdf)

This report describes the application of a bicycle and pedestrian use model developed to examine the impacts of shared-used paths in the Lake Tahoe, NV, region. Results are based on the estimated number of trips using any mode calculated by the Tahoe Regional Planning Agency's TransCAD traffic modeling software.

In Chapter 4.2, Impacts of Bicycle/Pedestrian Facilities on Vehicle-Miles of Travel (beginning on page 17 of the report, page 21 of the PDF), researchers noted that bicycle and pedestrian facilities "generally have two effects on overall VMT, which tend to offset each other. As discussed below, travelers who shift from an auto trip to a non-auto trip due to the presence of a facility result in a reduction in VMT, while persons who drive to a facility generate an increase in VMT."

In describing the overall change in VMT associated with the region's shared-use path facilities, researchers noted that "[a]dding the reduction in VMT associated with users who use the path instead of drive and the increase in VMT associated with auto access to the trails yields the total impact of each trail on overall VMT. All facilities were found to result in an increase in VMT."

The executive summary identifies ways that the development of new active transportation facilities can reduce VMT:

New facilities can reduce VMT by serving key transportation corridors, establishing the continuity of the network, and by discouraging parking at trailheads through a combination of limiting spaces, pricing and enforcement.

*Related Resource:*

**Bike Trail User Model**, Tahoe Regional Planning Agency, December 2009.

[http://tahoempo.org/bike\\_trail\\_model.aspx?SelectedIndex=3](http://tahoempo.org/bike_trail_model.aspx?SelectedIndex=3)

This web page provides links to the model used in the report cited above and instructions for its use. An excerpt from the web site:

As part of the Tahoe Basin Bicycle / Pedestrian Master Plan, LSC Transportation Consultants, Inc. with assistance from Alta Planning + Design developed a bicycle and pedestrian use level estimation model. The model estimates bicycle and pedestrian trips on Class I/Shared Use Paths and Class II/bicycle lanes for travel corridors in the Tahoe Region. This model is based upon observed facility use levels in the Tahoe Region, data regarding the characteristics of individual facility users, as well as demographic and travel data for the Tahoe region. Note that this model is for relatively urban or inter-community travel corridors, and is not applicable to mountain bike trails.

The model, which is used to help estimate the impacts of bicycling and walking region-wide for the Regional Plan update, can also be used to estimate bicycling and walking on individual trail segments.

## Oregon

**"Estimated VMT and GHG Emission Reductions Associated with the Going to the River Project,"** Ningsheng Zhou and Paul B. Smith, *ITE Journal*, Vol. 82, No. 5, pages 42-47, May 2012.

Citation at <http://trid.trb.org/view/2012/C/1148150>

From the abstract:

The "Going to the River" (Going) roadway project is an initiative in Portland, Oregon to provide improvements that will connect the existing bicycle/pedestrian network to a large nearby employment area. The project includes sidewalk infill, multiuse paths and neighborhood greenways improvements. In this study, a methodology is proposed to estimate the potential vehicle miles of travel (VMT) and greenhouse gas (GHG) impacts from the Going project. Three analysis modules were applied to estimate the VMT and GHG reductions: defining traffic patterns, estimating potential modal shift, and calculating VMT and GHG reduction. A mode shift lookup table was also developed to establish an evaluation base for all projects that cross the city. All the analyses used data from the City of Portland's regional transportation plan 2005/2035 transportation demand model. This method provides a way to quantitatively define and calculate the environmental impacts of a multimodal project at the sketch planning stage. The method is supported by the empirical

data, is sensitive to small-scale projects, and uses readily available modeling data. In the case study provided, the analysis indicated that the Going project decreases daily automobile vehicle trips by 4.5% and reduces daily VMT/GHG by 1.8% in the project's impact area.

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## Supplementary Information

We contacted Ningsheng Zhou to inquire about further development of the methodology used to examine the VMT and GHG impacts of the "Going to the River" project. Zhou indicated that no further work has been done on the project, nor has the methodology been applied to other projects.

Contact: Ningsheng Zhou, Senior Transportation Planner, Transportation Planning Division, Portland Bureau of Transportation, 503-823-7732, [ningsheng.zhou@portlandoregon.gov](mailto:ningsheng.zhou@portlandoregon.gov).

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## Vermont

**Economic Impact Study of Walking and Biking in Vermont**, Vermont Agency of Transportation, July 2012.

[http://vtransengineering.vermont.gov/sites/aot\\_program\\_development/files/documents/ltf/BikePedFinal%20Report%20Econ%20Impact%20Walking%20and%20Biking2012.pdf](http://vtransengineering.vermont.gov/sites/aot_program_development/files/documents/ltf/BikePedFinal%20Report%20Econ%20Impact%20Walking%20and%20Biking2012.pdf)

The following report excerpt, from page 73 of the PDF, highlights the challenges faced by agencies attempting to quantify how increased walking and biking translates to transportation system cost savings, which include reductions in VMT:

The potential transportation system cost savings are based on (1) the avoided consumer and public costs of automobile travel and (2) the added consumer and public costs of walking and biking. The potential transportation system cost savings related to walking and biking presented below are based on the assumption that that all walking and biking trips replace automobile trips. This assumption has the following limitations:

1. If it was not possible to walk or bike the trip may not be made (rather than shifting to travel by automobile). The result would be a reduction in trips if individuals do not have a car or the ability to drive; or if individuals choose not to travel for discretionary trips. If one assumes some trips are eliminated, the estimate of avoided costs presented below is high. However, there are other costs that cannot be explicitly accounted for due to reduced accessibility (if walking or biking were not possible) such as loss of independence, isolation, decreased access to jobs and services, and decreased economic activity. Thus, this limitation adds both upward and downward uncertainty into the analysis that from a total cost perspective minimizes its overall effect on the results.
2. The analysis of avoided costs assumes that an automobile trip would be the same distance as the walking or biking trip it replaces. However, travel time, rather than distance is often the determining factor when choosing a destination. For example, based on the 2009 NHTS data, the average distance for a trip made on foot in Vermont is 0.79 miles and takes approximately 16 minutes. During the same amount of time, an automobile traveling at an average speed of 30 miles per hour has a range of approximately 8 miles. If an individual has no choice but to drive, they may

choose destinations further away, with less travel time. This limitation would result in underestimating the amount of avoided vehicle miles of travel replaced by walking and biking.

## Washington

**An Assessment of Urban Form and Pedestrian and Transit Improvements as an Integrated GHG Reduction Strategy**, Lawrence D. Frank, Michael J. Greenwald, Sarah Kavage and Andrew Devlin, Washington State Department of Transportation, April 2011. <http://www.wsdot.wa.gov/research/reports/fullreports/765.1.pdf>

Researchers noted that this study, one of the first to test the effect of sidewalks on travel patterns, was “the first the authors know of to relate sidewalk availability with vehicle miles traveled (VMT) and greenhouse gas (GHG) emissions.” Using local sidewalk data layers for several areas in King County, WA, researchers examined pedestrian infrastructure and other investment and policy strategies associated with reduced VMT and CO<sub>2</sub>. Among the study findings:

- Results indicate that only moderate increases in sidewalk infrastructure may be needed to yield significant decreases in VMT and associated CO<sub>2</sub>. Conversely, more aggressive and substantial increases in land use mix may be required before a greater return on investment is realized.
- Other strategies contributing to a reduction in CO<sub>2</sub> and VMT include shorter transit travel and wait times, lower transit fares and higher parking costs.
- The lack of ability to collect sidewalk data from across all of King County limited the study results. The sample population was lacking in variation and skewed toward the more urban and walkable parts of King County.
- Researchers view this study as “an important first step towards a more complete understanding of how pedestrian investment, urban form, transit service and demand management (pricing) policy can interact to meet the state’s goals for VMT reduction. The inclusion of sidewalk data from across the entire county or region will provide further, and more conclusive, insights.”

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## Supplementary Information

To learn more about this research project and other relevant research conducted by Washington State DOT, we contacted Charlotte Claybrooke, Washington State DOT’s Active Transportation Programs Manager, and Lawrence Frank, the principal investigator for the April 2011 project.

Claybrooke reported that the agency does not have further experience with quantifying the impact of active transportation on GHG emissions and VMT other than that described in this report.

Frank was not available to address our questions at the time of publication of this Preliminary Investigation. He has written widely on the topic of active transportation and its impacts, and we have included some of those publications in this Preliminary Investigation.

#### Contacts:

- Charlotte Claybrooke, Active Transportation Programs Manager, Washington State Department of Transportation, 360-705-7302, [claybrc@wsdot.wa.gov](mailto:claybrc@wsdot.wa.gov).
  - Lawrence D. Frank, President, Urban Design 4 Health, Inc., 604-738-1588, [ldfrank@ud4h.com](mailto:ldfrank@ud4h.com).
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**Section 2.3, Bicycle Sketch Plan Methods**, Guidebook on Methods to Estimate Non-Motorized Travel: Supporting Documentation, Federal Highway Administration, July 1999. <http://www.fhwa.dot.gov/publications/research/safety/pedbike/98166/sec2.3.cfm>

While quite dated, we include this citation because of its apparent significance to this topic and to provide historical reference (the publication summarized here appears frequently in reference lists for publications on the topic of the relationship of walking and bicycling and VMT). This web site provides a description of the estimating tool described in the 1997 publication, Estimating the Effect of Bicycle Facilities on VMT and Emissions, by Stuart Goldsmith, Seattle Engineering Department. Goldsmith applied a sketch-plan method to estimate the impact of a new bicycle facility in the Seattle, WA, area on reducing motor vehicle VMT and emissions.

### **International Practices**

The publications below describe tools and models used in Canada and Ireland to assess the environmental impacts of active transportation.

**“Application of an Evidence-Based Tool to Evaluate Health Impacts of Changes to the Built Environment,”** Jared M. Ulmer, James E. Chapman, Suzanne E. Kershaw, Monica Campbell and Lawrence D. Frank, *Canadian Journal of Public Health*, Vol. 106, No. 1 (Supplement), pages eS26-34, July 2014.  
Citation at <http://www.ncbi.nlm.nih.gov/pubmed/25955544>

Excerpt from the abstract:

#### Methods:

Parcel land use and transportation system characteristics were calculated within a kilometre network buffer around each Toronto postal code. Built environment measures were linked with health and demographic characteristics from the Canadian Community Health Survey and travel behaviour from the Transportation Tomorrow Survey. Results were incorporated into an existing software tool and used to predict health-related indicators and GHG emissions for the Toronto West Don Lands Redevelopment.

#### Results:

Walkability, regional accessibility, sidewalks, bike facilities and recreation facility access were positively associated with physical activity and negatively related to body weight, high blood pressure and transportation impacts. When applied to the West Don Lands, the software tool predicted a substantial shift from automobile use to walking, biking and transit. Walking and biking trips more than doubled, and transit trips increased by one third. Per capita automobile trips decreased by half, and vehicle kilometres travelled and GHG emissions decreased by 15% and 29%, respectively.

#### Conclusion:

The results presented are novel and among the first to link health outcomes with detailed built environment features in Canada. The resulting tool is the first of its kind in Canada.

This tool can help policy-makers, land use and transportation planners, and health practitioners to evaluate built environment influences on health-related indicators and GHG emissions resulting from contrasting land use and transportation policies and actions.

**“Estimating the Potential Success of Sustainable Transport Measures for a Small Town,”** Seona Farrell, David McNamara and Brian Caulfield, *Transportation Research Record 2163*, pages 97-102, 2010.

Citation at <http://dx.doi.org/10.3141/2163-11>

From the abstract:

This paper examines the benefits of promoting and encouraging the use of soft modes of transport in a small town in Ireland. Currently, in the town in question, almost 70% drive to work alone each day. The Irish government recently adopted a policy of actively promoting and developing sustainable towns through the use of soft transport measures. This paper takes a typical town in Ireland and demonstrates how a modal shift toward sustainable transport measures could result in substantial savings in vehicle kilometers traveled and carbon dioxide (CO<sub>2</sub>) emissions. Census data were used to estimate the benefits of a modal shift from driving alone to walking, cycling, and carpooling. The COPERT IV model was used to estimate the reductions in CO<sub>2</sub> emissions if the estimated modal shifts were realized. Analysis of the commuting patterns of the individuals in the study area shows that the majority of car trips are less than 6 km. The results of the paper show that no one soft measure promoted in isolation is the silver bullet; rather, a mix of these options would be optimal for achieving a modal shift.

**“Macroscopic Model of Greenhouse Gas Emissions for Municipalities,”** Sybil Derrible, Sheyda Saneinejad, Lorraine Sugar and Christopher Kennedy, *Transportation Research Record 2191*, pages 174-181, 2010.

Citation at <http://dx.doi.org/10.3141/2191-22>

From the abstract:

In the challenge to reduce greenhouse gas (GHG) emissions from the transportation sector, urban municipalities hold significant responsibilities. The Municipal Transportation and Greenhouse Gas (MUNTAG) model was developed to help municipalities estimate their current transportation emissions, set future targets, and run forecasting scenarios and responses to policies. A set of seven criteria was adopted for the development of the model including low input, ease of use, and feasibility (i.e., the model includes only variables that are controlled by municipalities). The model contains five strategies: land use intensification, public transport, active transport, financial policies, and vehicle technology. Each use is addressed separately and then integrated into one working model. Motorized passenger kilometers traveled (PKT) per capita is first estimated with the gross domestic product per capita and population density. With transit infrastructure indicators, PKT per capita is calculated for each transit mode. Bicycle infrastructure is included to calculate the bicycle mode share. Response to several financial policies (e.g., parking price, area pricing) can be modeled by using elasticity statistics gathered from the literature. Finally, changes in vehicle technology (e.g., hybrid electric vehicles) can be modeled by adjusting the various emission factors. One advantage of the model is that all parameters can be adapted fairly easily to account for municipal specificities. Overall, it is a macroscopic, aggregate, and static model suited for medium-sized and large municipalities that can be useful as a screening tool.

## **The Built Environment and Active Transportation**

**Land Use Impacts on Transport: How Land Use Factors Affect Travel Behavior**, Todd Litman and Rowan Steele, Victoria Transport Policy Institute, August 2015.

<http://www.vtpi.org/landtravel.pdf>

This paper examines how a wide range of factors affect transportation activity. A discussion of the conditions that encourage the use of active transportation (walking and cycling) begins on page 24 of the report. A summary of nonmotorized indirect travel Impacts on page 27 notes the following:

The previous analysis suggests that each mile of increased non-motorized travel resulting from walking and cycling improvements typically reduces five to fifteen motor vehicle-miles through leverage effects. Conventional planning analysis generally ignores these indirect impacts and so underestimates the potential of non-motorized transport improvements to achieve benefits such as reduced traffic congestion, accidents and pollution emissions. Considering these indirect impacts tends to increase estimated benefits by an order of magnitude, justifying much greater support for non-motorized transport. It is therefore important to understand these impacts.

**Active Travel Co-Benefits of Travel Demand Management Policies That Reduce Greenhouse Gas Emissions**, Caroline J. Rodier, Richard Lee, Brandon Haydu and Nicholas J. Linesch, Caltrans and U.S. DOT, April 2014.

<http://transweb.sjsu.edu/PDFs/research/1109-active-travel-greenhouse-gas-reduction.pdf>

Researchers noted that results of the comparative risk assessment model I-THIM “give us important insight into what is possible if policies supportive of active transport were to be aggressively implemented in a region; however, they do not tell us the magnitude of change that may result from specific changes in different types of land use and transportation policies and plans. In sum, these studies tell us what is possible, but not what it might take to get there.”

In this study, researchers used California’s activity-based travel demand model to show how “the new generation of travel models can be used to produce the active travel data (age and sex distributions) required by I-THIM to estimate health outcomes for regional land use and transport plans and to (2) identify the magnitude of change in active travel possible from land use, transit, and distance-based vehicle pricing policies for California and its five major regions for a future 2035 time horizon.”

From the study results:

- Distance-based vehicle pricing may increase walking by about 10% and biking by about 17%, and concurrently GHG from VMT may be reduced by about 16%.
- Transit expansion and supportive development patterns may increase active travel by about 2% to 3% for both walk and bike modes while also reducing VMT by about 4% on average.
- The combination of all three policies may increase time spent walking by about 13% and biking by about 19%, and reduce VMT by about 19%.

(I-THIM is also addressed in a November 2011 California Department of Public Health report cited earlier in this Preliminary Investigation; see page 8.)

**Tools for Estimating VMT Reductions from Built Environment Changes**, Anne Vernez Moudon and Orion Stewart, Washington State Department of Transportation, June 2013.  
<http://depts.washington.edu/trac/bulkdisk/pdf/806.3.pdf>

Excerpt from the introduction:

Part of the research conducted for this project focused on identifying the indicators known to affect [nonmotorized travel (NMT)] and the tools that decision-makers can use to understand how proposed transportation and land use changes will affect travel. Extensive research has been conducted over the past two decades on the relationship between individual, household, land use and built environment (BE) *factors* associated with transit and NMT. This past research has provided a foundation for numerous *tools* that attempt to forecast the impact of land use and transportation system changes on transit, NMT, VMT, GHG emissions, and other travel-related outcomes. This report first summarizes the individual, household, and BE *factors* associated with NMT. It then reviews the *tools* that use those factors as inputs to predict travel behaviors and related outcomes.

**Effects of the Built Environment on Transportation: Energy Use, Greenhouse Gas Emissions, and Other Factors**, *Transportation Energy Futures Series*, National Renewable Energy Laboratory and Cambridge Systematics, Inc., March 2013.

<http://www.nrel.gov/docs/fy13osti/55634.pdf>

The authors note that tools to measure impacts of the built environment on GHG emissions are lacking. From page 66 of the report (page 78 of the PDF):

Most tools used to assess relationships between transportation and land use, ranging from simple spreadsheet-based sketch methods to complex network-based travel demand and integrated land-use models, are not ideally suited for measuring all aspects of the built environment's effects on travel. The best for this purpose are probably the more well-developed regional travel demand models that incorporate transit and nonmotorized mode choices, as well as factors that reflect built environment variables, such as the quality of the pedestrian environment and mix of uses. While travel demand models are used for metropolitan transportation planning throughout the United States, they are resource intensive to apply, and few have benefited from the enhancements required to adequately model built environment factors. Sketch-level tools are more widely used, but primarily account for neighborhood-level factors rather than regional patterns of accessibility. New and enhanced tools are needed to accurately and comprehensively model these complicated relationships.

**“Models for Anticipating Non-Motorized Travel Choices, and the Role of the Built Environment,”** Mobashwir Khan, Kara M. Kockelman and Xiaoxia Xiong, *TRB 92nd Annual Meeting Compendium of Papers*, Paper #13-1240, 2013.

Citation at <http://trid.trb.org/view.aspx?id=1240890>

Excerpt from the abstract:

This paper uses detailed travel data from the Seattle metropolitan area to evaluate the effects of built-environment variables on the use of non-motorized (bike + walk) travel modes. Several model specifications are used to understand and explain non-motorized travel behavior in terms of household, person and built-environment (BE) variables. Marginal effects of covariate effects for models of vehicle ownership levels, intrazonal trip-making, destination and mode choices, non-motorized trip counts per household, and miles traveled (both motorized and non-motorized) are presented .... The results underscore the importance of street connectivity (quantified as the number of 3-way and 4-way intersections in a half-mile radius), higher bus stop density, and greater nonmotorized access in

promoting lower vehicle ownership levels (after controlling for household size, income, neighborhood density and so forth), higher rates of non-motorized trip generation (per day), and higher likelihoods of non-motorized mode choices. Intrazonal trip likelihoods rose with street connectivity, transit availability, and land use mixing. Across all BE variables tested, street structure offered the greatest predictive benefits, alongside accessibility indices (for both motorized and non-motorized access). For example, non-motorized trip counts are estimated to rise 7% following a 1% increase in this variable, and walk probabilities by 27% following a one standard deviation increase in this index at the destination zone. Regional and local accessibility and density (of population plus jobs) variables were also important, depending on response being modeled. Simulated model applications illuminate when and to what extent significant travel behavior changes may be witnessed, as land use settings and other variables are changed.

**UrbanFootprint**, Technical Summary, Model Version 1.0, Calthorpe Associates, July 2012.

<http://www.scag.ca.gov/Documents/UrbanFootprintTechnicalSummary.pdf>

This summary of UrbanFootprint, a “land use planning, modeling, and data organization framework,” includes a discussion of the model’s public health module (see page 29 of the document). The module includes metrics for physical activity-related weight and disease incidences, pedestrian safety measures and respiratory impacts.

A November 2013 scope of work considered by the Sacramento Area Council of Governments (SACOG) Board of Directors (see Related Resource) identifies proposed enhancements to the public health metrics associated with UrbanFootprint. The enhancements are expected to provide “a broader and more robust analysis methodology on public health impacts related to SCS [Sustainable Communities Strategy] and transportation-land use plans throughout the state.”

*Related Resource:*

**“Consultant Services to Improve the UrbanFootprint Public Health Module,”** Action Item #13-11-11, SACOG Board of Directors, November 2013.

<http://www.sacog.org/calendar/2013/11/board/pdf/11-UrbFootprint.pdf>

This recommendation prepared for consideration by the SACOG Board of Directors includes a draft scope of work that describes further development of the public health module of the UrbanFootprint scenario planning model.

**TCRP Report 95: Traveler Response to Transportation System Changes;** Chapter 16, Pedestrian and Bicycle Facilities, Third Edition, 2012.

[http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp\\_rpt\\_95c16.pdf](http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_95c16.pdf)

This chapter of TCRP Report 95 “examines pedestrian and bicyclist behavior and travel demand outcomes in a relatively broad sense. It covers traveler response to NMT facilities both in isolation and as part of the total urban fabric, along with the effects of associated programs and promotion. It looks not only at transportation outcomes, but also recreational and public health outcomes.”

A discussion of traffic, energy and environmental relationships, which begins on page 16-386 of the report (page 398 of the PDF), includes a review of the literature that addresses the impact of pedestrian and bicycle facilities from the perspectives of driving avoidance estimates, facility and project impacts, and program impact model findings. An extensive list of references that begins on page 16-442 of the report (page 454 of the PDF) provides sources for further research on this topic.

**Strategy Toolbox for the Portland Metropolitan Region**, Climate Smart Communities: Scenarios Project, Oregon Department of Transportation, U.S. Department of Transportation, Federal Highway Administration and Federal Transit Administration, October 2011.  
[http://www.oregonmetro.gov/sites/default/files/planning\\_and\\_development\\_regional\\_trans\\_reduction\\_strategies\\_and\\_the\\_benefits\\_they\\_bring\\_to\\_the\\_region\\_october\\_2011.pdf](http://www.oregonmetro.gov/sites/default/files/planning_and_development_regional_trans_reduction_strategies_and_the_benefits_they_bring_to_the_region_october_2011.pdf)

This toolbox presents “research related to land use and transportation strategies that can be applied to reduce greenhouse gas (GHG) emissions from light duty vehicles in the Portland metropolitan region.”

An examination of the relationship between active transportation and GHG emissions begins on page 31 of the report (page 39 of the PDF). The authors summarize research findings on the potential to reduce GHG emissions through the use of active transportation and a complete streets design strategy. A brief case study examines the effects of bicycle investments in Portland, OR. Addressing the caveats on research, the authors note:

Interpreting GHG emissions reduction estimates and cost effectiveness requires caution; there are many complicating factors that create the context for the effectiveness of a given strategy (e.g. land use, density, etc.). The complexity of the interactions of land use, transportation and other factors make it very difficult to isolate the impact of any individual strategy.

Additionally, no studies have been conducted that provide evidence of the impact this strategy has on reducing GHG emissions *directly*. But, an increase in bicycling and walking trips (including those that lead to transit trips) can be translated into reductions of VMT, which translates to reductions of GHG emissions.

**“Travel and the Built Environment: A Meta-Analysis,”** Reid Ewing and Robert Cervero, *Journal of the American Planning Association*, Vol. 76, No. 3, pages 265-294, 2010.

<http://www.arch.utah.edu/cgi-bin/wordpress-metroresearch/wp-content/uploads/2013/09/Most%20Cited%20Articles/Ewing&Cervero.pdf>

Researchers conducted a meta-analysis of literature available through 2009 on the association of the built environment and travel. The authors concluded that “[w]alking is most strongly related to measures of land use diversity, intersection density and the number of destinations within walking.”

Tables summarizing study results related to the relationship of walking to density, diversity, design, destination accessibility, transit access and neighborhood type begin on page 23 of the article (page 24 of the PDF).

**“Effect of Street Network Design on Walking and Biking,”** Wesley E. Marshall and Norman W. Garrick, *Transportation Research Record 2198*, pages 103-115, 2010.

Citation at <http://trid.trb.org/view.aspx?id=909985>

From the abstract:

The objective of this research was to investigate whether a relationship existed between street network characteristics and the transportation modes selected in a neighborhood. Factors such as street characteristics, vehicle volumes, activity levels, income levels, and proximity to limited-access highways and the downtown area were controlled for. The results suggested that all three of the fundamental characteristics of a street network—street connectivity, street network density, and street patterns—were statistically significant in

affecting the choice to drive, walk, bike, or take transit. Both increased intersection density and additional street connectivity were generally associated with more walking, biking, and transit use. Street patterns with gridded street networks, which tended to have a higher-than-average street connectivity and a much higher street network density, were associated with much more walking and biking. These results suggested that street network patterns were extremely important for encouraging nonautomobile modes of travel. As the United States begins to focus on reducing vehicle miles traveled as a strategy to combat carbon production and cut energy use, it is increasingly imperative that this relationship between the built environment and mode choice be accounted for in the planning and design of the transportation system.

**“Power to the Pedals,”** Gary Gardner, *World Watch Magazine*, Vol. 23, No. 4, July/August 2010.

<http://www.worldwatch.org/node/6456>

This article examines the impact of cycling and the “infrastructure tools” that can help increase bicycling rates. The author provides a case study of the impact of biking policies in a German city and highlights policies supported by other European cities that have encouraged increases in biking.

**“Carbonless Footprints: Promoting Health and Climate Stabilization Through Active Transportation,”** Lawrence D. Frank, Michael J. Greenwald, Steve Winkelman, James Chapman and Sarah Kavage, *Preventive Medicine*, Vol. 50, Supplement, pages S99-S105, January 2010.

<http://www.sciencedirect.com/science/article/pii/S0091743509004873>

Excerpt from the abstract:

#### *Objective*

Our objective was to describe how active transportation can help meet health and greenhouse gas emissions goals, and the ability of urban form strategies to impact both issues. In addition, we wanted to assess if there is an inverse relationship between active and motorized forms of travel.

#### *Methods*

A cross-sectional analysis of travel diary data was used to measure relationships among energy (kcal) burned from walking, energy (kcal) burned from motorized transportation, and the ratio of the two (the transport energy index) with regional accessibility and local walkability when adjusting for demographic factors. Multiple linear regression and descriptive statistics were employed to estimate these relationships.

#### *Results*

Transit accessibility, residential density, and intersection density were positive predictors of walk energy and the energy index and inverse predictors of motorized energy. The land use mix variable was negatively and significantly associated with energy burned from walking and from motorized transportation, with no significant impact on the transport energy index. Because a mixed land use pattern places destinations closer together, it reduces distances and thus energy demands for both walking and driving.

#### *Conclusions*

The results support the concept, previously untested empirically, that similar urban form strategies can have cobenefits for both physical activity and climate change.

**New Data for a New Era: A Summary of the SMARTRAQ Findings**, Linking Land Use, Transportation, Air Quality and Health in the Atlanta Region, David Goldberg, Barbara McCann, Lawrence Frank, Jim Chapman and Sarah Kavage, January 2007.

[http://www.smartgrowthamerica.org/documents/SMARTRAQSummary\\_000.pdf](http://www.smartgrowthamerica.org/documents/SMARTRAQSummary_000.pdf)

The SMARTRAQ research project began in 1998 in response to a transportation plan for the Atlanta region that forecast emissions standards in violation of the federal Clean Air Act. The goal of the project was to “provide a framework for assessing which combinations of land use and transportation investment policies have the greatest potential to reduce the level of auto dependence while promoting the economic and environmental health of the Atlanta metropolitan region.” An excerpt from the executive summary:

**Neighborhood walkability is linked to fewer per capita air pollutants.** The SMARTRAQ air quality analysis found that each step up the five-part walkability scale results in a 6 percent reduction in NO<sub>x</sub> and a 3.7 percent reduction in VOC, which combine to form ozone. Ozone is Atlanta’s biggest air quality problem and has been linked to respiratory illnesses.

**Neighborhood walkability is linked to fewer per capita greenhouse gases.** Carbon Dioxide (CO<sub>2</sub>) is the primary contributor to greenhouse gases and global warming. Travel patterns of residents in the region’s least walkable neighborhoods generated about 20 percent higher CO<sub>2</sub> emissions than travel by those who live in the most walkable neighborhoods – about 2,000 extra grams of CO<sub>2</sub> per person each weekday.

## Contacts

CTC contacted the individuals below to gather information for this investigation.

### **State Agencies**

#### **Oregon**

Geoff Crook  
Sustainability Program Manager, Statewide Programs Unit  
Oregon Department of Transportation  
503-986-3425, [geoff.s.crook@odot.state.or.us](mailto:geoff.s.crook@odot.state.or.us)

#### **Washington**

Charlotte Claybrooke  
Active Transportation Programs Manager  
Washington State Department of Transportation  
360-705-7302, [claybrc@wsdot.wa.gov](mailto:claybrc@wsdot.wa.gov)

### **Local and Regional Agencies**

#### **Georgia**

David D'Onofrio  
Principal Planner, Air Quality & Climate Change  
Atlanta Regional Commission  
404-463-3268, [ddonofrio@atlantaregional.com](mailto:ddonofrio@atlantaregional.com)

#### **Nevada**

Morgan Beryl  
Associate Transportation Planner  
Tahoe Regional Planning Agency  
775-589-5208, [mberyl@trpa.org](mailto:mberyl@trpa.org)

#### **Oregon**

Ningsheng Zhou  
Senior Transportation Planner, Transportation Planning Division  
Portland Bureau of Transportation  
503-823-7732, [ningsheng.zhou@portlandoregon.gov](mailto:ningsheng.zhou@portlandoregon.gov)

### **Private Firms**

Lawrence D. Frank  
President  
Urban Design 4 Health, Inc.  
604-738-1588, [ldfrank@ud4h.com](mailto:ldfrank@ud4h.com)