Fehr & Peers
Transportation Consultants

Assessment of

Greenhouse Gas Analysis Tools

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Innovation is in our nature.

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Prepared By: Fehr & Peers Transportation Consultants AECOM

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Project Team

Department of Commerce

Karen Larkin, Assistant Director, Local Government Division
Leonard Bauer, Managing Director, Growth Management Services
Joyce Phillips, Senior Planner, Growth Management Services (Project Manager)

Fehr & Peers

Don Samdahl, Principal
John Davies, Associate
Chris Breiland, Senior Transportation Engineer
Virginia Brix, Technical Editor
Tiiki Rysen, Graphic Specialist

AECOM

Honey Walters, Associate Principal
Austin Kerr, Air Quality and Noise Analyst
Nancy Bird, Senior Planner

Technical Review Team

Association of Washington Cities

Dave Williams, Municipal Policy Associate
Sheri Sawyer, Municipal Government Analyst

Washington State Association of Counties

Scott Merriman, Deputy Director
Josh Weiss, General Counsel/Policy Director

Regional Transportation Planning Organizations

Jeff Wilkens, Executive Director, Wenatchee Valley Transportation Council

Regional Transportation Planning Organizations

Anne Criss, Climate Change Program Lead
Brian Smith, Director, Strategic Planning & Programming
Judy Lorenzo, Statewide Planning Policy Branch Manager
Timothy Sexton, Air Quality, Noise and Energy Policy Manager
Jason Beloso, Policy Advisor

Washington State Department of Ecology

Gail Sandlin, Air Quality Environmental Specialist 4

Washington State Department of Commerce

Gustavo Collantes, Senior Energy Policy Specialist

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CHAPTER 1. INTRODUCTION

A growing body of research has indicated that greenhouse gas (GHG) emissions caused by human activity is changing the global climate in ways that could be detrimental to our future health and wellbeing. Like several other states, Washington has passed legislation aimed at reducing GHG emissions. This chapter provides a brief history of the GHG-related legislation and a summary of the legislative requirements. This chapter also summarizes how regional and local agencies are currently analyzing GHG emissions voluntarily and introduces a methodology to identify a set of tools that can be used by a variety of agencies to estimate GHG emissions.

State Actions to Address Climate Change through the Growth Management Act

Washington State Senate Bill - ESSB 6580 directed the Washington State Department of Commerce to produce a report identifying potential amendments to the Growth Management Act and related statutes, that would better enable state and local governments to address climate change issues through land use and transportation planning. The report was developed with input from the Land Use and Climate Change Advisory Committee (LUCC), made up of legislators, county and city elected officials, tribes, business, and other interests. The report was issued in December 2008.

The recommendations in the Department of Commerce report proposed to amend the State's Growth Management Act (GMA) and related statutes to enable State and local governments to address climate change issues and to reduce dependence on foreign oil through land use and transportation planning processes.

LEGISLATIVE BACKGROUND

In an effort to reduce Washington State's contribution towards the effects of climate change, Engrossed Substitute Senate Bill 6001 (ESSB 6001) was adopted in 2007 to establish GHG emission reduction goals for the State. Those reduction targets became law when a separate bill (HB 2815) was passed in 2008. This new law states that GHG emissions must be reduced to 1990 levels by January 1, 2020; to 25 percent below 1990 levels by January 1, 2035; and to 50 percent below 1990 levels by January 1, 2050.[1]

To assist State and local agencies in meeting the GHG emissions reduction targets described above, in 2008 the Legislature adopted ESSB 6580[2], recognizing the following:

- Patterns of land use development influence transportation-related greenhouse gas emissions and the need for foreign oil;
- Fossil fuel-based transportation is the largest source of greenhouse gas emissions in Washington; and,
- The State and its residents will not achieve the [GHG] emissions reductions defined above without a significant decrease in transportation emissions.

Based on these findings, the Legislature determined that it is in the public interest to aid in the development of policies, practices, and methodologies that may assist counties and cities in addressing challenges associated with greenhouse gas emissions and dependence on foreign oil.

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[1] *Addressing Climate Change through Comprehensive Planning under the Growth Management Act*, December 2008, CTED, pp. 4-6.

[2] *Certification of Enrollment Engrossed Substitute Senate Bill 6580,* March 10, 2008, 60th Legislature 2008 Regular Session, Section 1.

Section 2 of ESSB 6580 (2008) required the Washington State Department of Commerce (Commerce)[3] to develop and provide to counties and cities a range of advisory climate change response methodologies, guidance on tools to measure GHG emissions, a computer modeling program, and estimates of GHG emissions reductions resulting from specific policies and measures. This report has been prepared to assist Commerce in meeting its obligations under ESSB 6580.

Washington State resources regarding climate change are available at the Department of Ecology's website (http://www.ecy.wa.gov/climatechange/index.htm). The site contains information related to the mitigation of greenhouse gas emissions, adaptation to climate change impacts, and historical documents from the Climate Advisory Team and the subsequent Climate Action Team. In addition, the Department of Commerce provides information related to climate change and comprehensive planning at its website (http://www.commerce.wa.gov/site/1105/default.aspx).

CURRENT GHG EVALUATION EFFORTS

To better understand how local and regional agencies are currently evaluating GHG emissions and what analysis and staff resources are available to them, the project team interviewed staff at a variety of Regional Transportation Planning Organizations (RTPOs) as well as county and city governments. The interviews were intended to provide a reality "spot check" of jurisdictional resources rather than a scientifically rigorous survey (refer to **Appendix A** for compiled interview data). Fifteen agencies in urban and rural areas of the State responded to our inquiries. Transportation and planning professionals from the following jurisdictions participated:

- Puget Sound Regional Council (PSRC)
- Whatcom Council of Governments (WACOG)
- Wenatchee Valley Transportation Council (WVTC)
- Thurston County Regional Council (TCRC)
- Spokane Regional Council (SRC)
- Snohomish County
- Yakima Valley Council of Governments
- City of Tacoma
- King County
- Clark County
- City of Everett
- City of Spokane
- City of Seattle
- City of Port Angeles
- City of Ellensburg

We asked a set of standardized questions to each respondent, recognizing that agencies and government entities will likely choose a GHG analysis approach based on the type of analysis required and the amount of available resources. The questions included:

1) Do you have an initiative for air quality? Does it entail measuring GHG emissions? If so, what tool are you using to collect data?
2) What other jurisdictions are you coordinating with on air quality or transportation modeling efforts?
3) What transportation model do you use, if any? What staff resources do you have for running it? If using a specific model, have you altered it in any useful way?
4) Do you have GIS? What staffing resources support GIS? How do they get updated?

[3] Prior to July 2009, Commerce was named the Washington State Department of Community, Trade and Economic Development.

5) Do you use in-house staff resources or consulting assistance to collect air quality or transportation data?
6) What land use tools do you have to help measure future quality initiatives?
7) If you were to model GHG production in the future, what tool would you feel most comfortable using?

Our Interviewers also asked impromptu follow-up questions to help understand other pressing concerns of the directors and technical practitioners of these jurisdictions related to air quality.

Summary of Interview Comments

This section summarizes information gleaned from the interviews.

Air Quality Initiatives

Most of the RTPOs and several county and municipal jurisdictions interviewed had general policy directives to improve air quality. The RTPOs were more likely to indicate that they are working towards measuring some level of GHG emissions. Most cities and counties interviewed that were engaged in air quality improvements had begun at the operational level, versus direct county- or city-wide planning for GHG reductions.

Jurisdictional Coordination

As expected, the cities and counties interviewed have historical relationships with their RTPOs related to transportation demand forecasting and some level of emission calculations related to individual sites. Otherwise, air quality partnerships between different cities or counties were not reported.

Software Resources

The RTPOs interviewed are using the following transportation modeling programs: EMME, TransCAD, or Visum. Counties interviewed are using EMME, Mobile 6, Visum, or the ICLEI CACP software. Not all cities interviewed had transportation models. Of those that did, EMME and Synchro were the most common.

All jurisdictions interviewed had ArcGIS software.

Staffing Resources

The RTPOs interviewed appeared to have adequate staffing capacity for current transportation modeling needs. However, some RTPOs said they would need new resources to perform additional analysis. Staff of county and city governments interviewed expressed the inadequacy of staffing for existing modeling exercises and concern regarding potential future mandates related to air quality. The two cities interviewed do not have in-house staff resources for planning-related modeling efforts and rely on consultant expertise to carry out these tasks.

Individual Suggestions Related to Data Collection of GHG Emissions

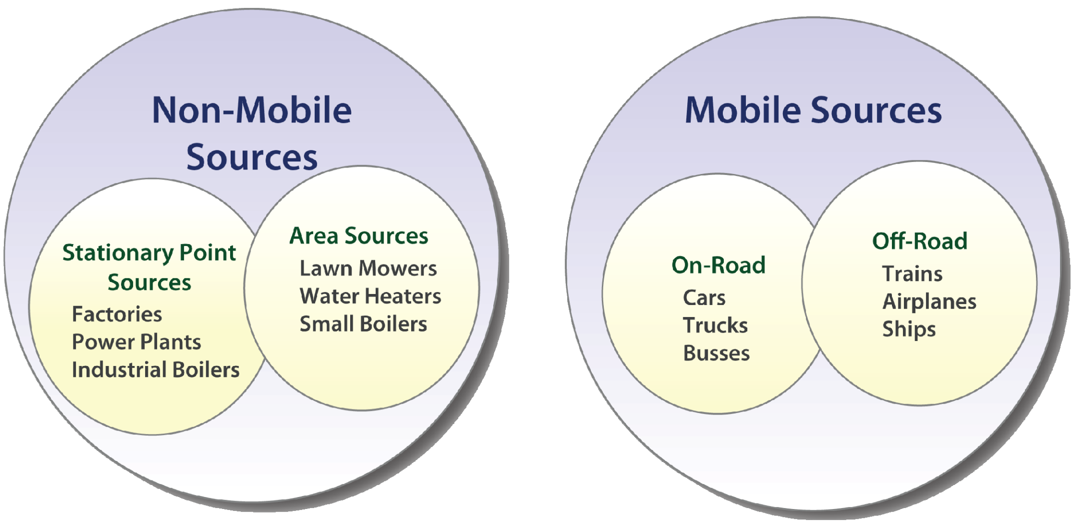
When directly asked for suggestions on how best to measure GHG emissions or thoughts on collecting air quality data, several practitioners articulated professional opinions worthy of sharing in this paper. These comments reflect a variety of opinions on different aspects of the issue and are included in **Appendix A**.

IDENTIFYING TOOLS TO EVALUATE GHG EMISSIONS

The outcome of the interviews described above indicates that regional and local agencies are taking different approaches when it comes to evaluating GHG emissions. Some jurisdictions have the tools and resources to evaluate GHG emissions in-house, other jurisdictions hire consultants to execute these tasks, while some jurisdictions have not begun to measure GHG emissions.

Given the legislative requirements to reduce GHG emissions in the state, and Commerce's role in assisting agencies who choose to voluntarily address GHG reductions through planning efforts, the remainder of this report identifies tools to estimate and analyze GHG emissions. This report focuses on tools that can estimate on-road mobile-source GHG emissions since these vehicles are the State's single largest source of GHG emissions, accounting for more than 35 percent of all emissions[4]. The remaining GHG emissions related to land use development are generated by off-road vehicles (e.g., construction equipment, planes, trains), stationary sources, including area sources (e.g., space and water heating, landscape maintenance equipment) and indirect point sources (e.g., electricity consumption, water production and distribution, etc.). See **Figure 1** for a depiction of the GHG emissions sources related to land use development. Tools for estimating GHG emissions from area and indirect sources are not addressed in this report, although tools that can identify both mobile and non-mobile emissions are highlighted.

Figure 1. GHG Emissions Sources from Land Use Development



APPLICATION OF THE GHG EVALUATION TOOLS

The GHG tools described in this report are applicable to a wide range of land use and transportation planning activities within Washington State. They include the following:

[4] Note: Overall transportation-related GHG emissions (including on-road and off-road sources) accounted for 47% of the State's GHG emissions in 2005. Source: Washington State Department of Ecology. *Washington State Greenhouse Gas Inventory and Reference Case Projections, 1990-2020* http://www.ecy.wa.gov/climatechange/docs/WA_GHGInventoryReferenceCaseProjections_1990-2020.pdf December 2007.

- Regional plans
- City or County-wide plans
- Subarea plans
- Site-level plans
- Corridor plans

These GHG tools can be used by regional and local agencies throughout the state to help decision-makers consider likely emissions resulting from various land use and transportation planning scenarios. Regional Transportation Planning Organizations (RTPOs) can use these tools to calculate the GHG effects of regional land use allocations, transportation networks, and policy decisions at a broad planning level. For example, the Puget Sound Regional Council is completing a major study of land uses, multi-modal transportation investments, and roadway pricing strategies. These broad alternatives are being analyzed using the Puget Sound Regional Council (PSRC) travel demand model and the U.S. Environmental Protection Agency (EPA) Motor Vehicle Emissions Simulator (MOVES) GHG emissions model. Similarly, cities and counties can test the GHG effects of land use and transportation strategies either at a jurisdiction-wide level or within subareas. For instance, King County has completed a subarea GHG analysis of the White Center subarea in Seattle using an adaptation of the PLACE^{3}S software program.

Traditionally, GHG tools have been applied at the project, or site-level to estimate the effects of individual development proposals. Agencies will find the tools to be applicable both at the site level as well as for larger mixed use projects that involve the interaction of different land uses and travel patterns. The GHG tools can be applied for corridor plans involving multiple modes. Several WSDOT corridor plans have recently included GHG studies using combinations of tools described in this report. Ultimately, the tools identified in this report will be useful in measuring, modeling, and forecasting GHG emissions as the state develops its statewide climate strategy.

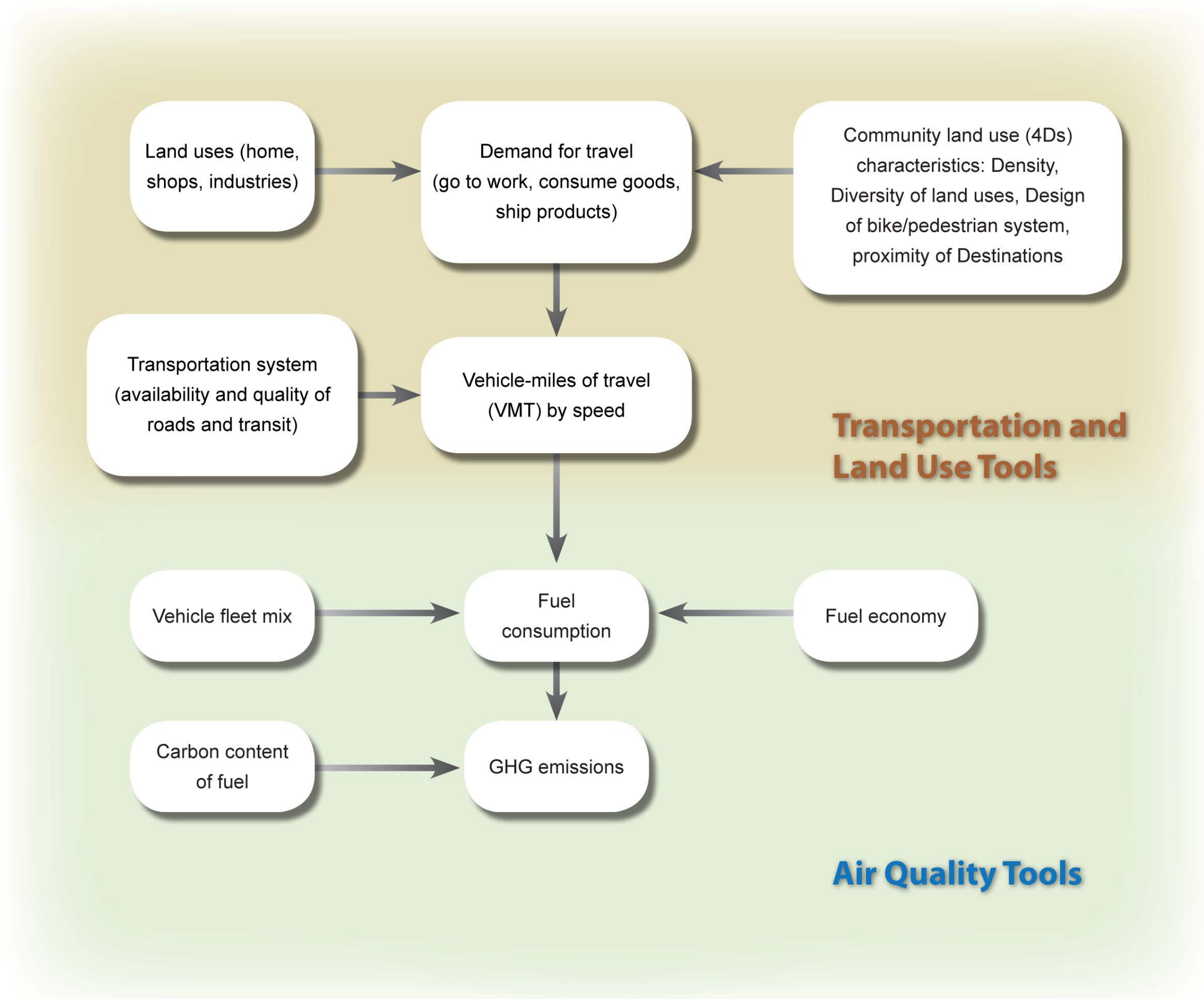
In addition, some of the more sophisticated tools will allow for the input of localized travel data, or allow/account for changes in the vehicle fleet (e.g., a greater number of hybrid or electric vehicles as their use increases over time), or changes in fuel economy to be incorporated into the analysis.

Some tools are useful at both the comprehensive planning level and at project-level review. This analysis focused on tools most useful at the comprehensive plan or sub-area plan level. There has been a growing demand for tools that are appropriate for project-level review. Please note that in the “Range of Applicability” column of Appendix B, tools that are useful at the project level were noted.

CHAPTER 2. DESCRIPTION OF AVAILABLE TOOLS

There are a wide variety of tools that can evaluate mobile-source GHG emissions. To prepare for the initial screening, the project team identified over 60 tools in the spring of 2009 and grouped them into two major categories: (1) Transportation and Land Use and (2) Air Quality. This categorization is relevant since the Transportation and Land Use tools typically rely on different inputs than the Air Quality tools. While there are several integrated Transportation/Land Use/Air Quality tools available, most Air Quality tools are run independently and rely on output generated by Transportation and Land Use tools, as shown in **Figure 2.** Within each category, the project team sorted tools according to type (e.g., spreadsheets, modeling software, calculators, and methodology protocols) and this categorization was carried through the first level screening.

Figure 2. Relationship between Land Use, Transportation, and Mobile-Source GHG Emissions



FIRST LEVEL SCREENING OF THE GHG TOOLS

The following section describes the screening criteria and results of the first level evaluation.

GHG Screening Criteria

To narrow the list of available tools into a shortlist of those that are most practical across a range of applications and conditions, the project team developed a set of screening criteria with the assistance of a Technical Review Team, comprised of Commerce, other state agencies, the Association of Washington Cities, and the Washington State Association of Counties. **Table 1** lists the criteria used for the screening process. In addition to these criteria, the tool's range of applicability, including regional planning, city/county level planning, subarea planning, or project-level planning is also identified.

Table 1. Screening Criteria

Criteria	Comment
Applicability for community plans	Can the tool be used across the range of potential planning applications, or is it focused at the project level?
Availability to Public Agencies	Some tools are proprietary or not readily available to public agencies. If not proprietary, is the tool easy to update as the community changes or does the tool need to be tailored to the community?
Sensitivity to land use changes	Can the tool be used to reflect changes in land use patterns or level of intensity?
Sensitivity to transportation changes	Can the tool measure changes in transportation network or performance?
Adaptability to Washington State conditions	Are the tool parameters able to be adapted to conditions in Washington State (e.g., geographic, climatic, demographic differences)?
Use of available data	Can the tool run on data commonly collected and used in planning and public works departments (GIS layers for land use designations; transportation networks; census data; commonly run transportation models) or are special studies (surveys, origin and destination) and other data collection efforts required?
Uses of available hardware	Can the tool be run on computers typically found in a community planning or public works department?
Accuracy	Can the tool accurately estimate mobile-source GHG emissions? (e.g., dependent on accurate VMT, speed, emissions factors, local fleet mix data).

Screening Process

For each criterion described above, we evaluated the tools on a three-point scale:

1 = No; Not Applicable

2 = Maybe; Some applicability

3 = Yes; Highly applicable

The tools were tabulated in a screening table and the scores were recorded (See **Appendix B**). The ratings were then summed across the criteria to produce a composite score for each tool. The composite scores were examined and the project team selected a short list of the tools most applicable and adaptable to the needs of local and regional agencies within the State. Since several of the tools produce similar results and have common characteristics, the project team's experience using the tools was also considered. The evaluation was not intended to reject any tools or models, but to evaluate and refine the long list of available tools.

In screening the tools, the project team considered the following information:

- The team's knowledge of the tool and experience using the tool
- Information about the tool available from literature reviews (preferably from vendor or academic sources)
- Examination of calculation methods downloaded from the web (e.g., inputs, calculations, formulas)

The resulting evaluation produced several insights into the available tools.

Screening Results

The following section summarizes our findings and highlights the strengths and weaknesses of key tools.

Transportation and Land Use Planning Tools

As shown in **Figure 2**, the key GHG-related output of transportation and land use planning tools is an estimate of vehicle miles of travel (VMT), often stratified by travel speed. VMT is the principal output variable from these types of models because the relationship between land use and VMT is well understood. With assumptions about fuel economy, vehicle fleet mix, and other factors (described in the Air Quality Tools section) VMT can be used to estimate mobile-source GHG emissions.

The following transportation and land use planning analysis tools described are ordered in increasing level of complexity, starting with spreadsheet tools and ending with advanced traffic assignment models. The project team identified selected tools within each sub-category that warrant further evaluation. See **Appendix B** for additional details about all the tools that were evaluated.

Spreadsheet Tools

A variety of spreadsheet tools have been developed by agencies and consultants to estimate changes in travel demand and VMT. In general, these spreadsheets work by estimating the number of vehicle trips from a land-use project. Providing an average trip length, VMT and/or GHG emissions are estimated.

Many of the spreadsheet tools have limited applicability because they cannot analyze the GHG emissions related to transportation projects (new or expanded roads and transit service), or they are too simplistic to account for the complexity of a typical mixed-use land development project. For example, the **Center for Clean Air Policy (CCAP) Spreadsheet** is helpful in that it gives rules-of-thumb related to the impacts of various policies, but it is not able to test or model land use scenarios without estimating complex inputs like vehicle trip generation, mode split, and average trip lengths. Similarly, the **King County State Environmental Policy Act (SEPA) GHG Emissions Worksheet** is easy to use, but only includes 17 land use types and is geared to project level, rather than the plan level applications. Potential limitations of the worksheet also include the possibility of double-counting GHG emissions for multiple land uses and a lack of variables to reflect differences in trip rates and trip length (and, therefore VMT) associated with different demographic groups and land use types. These limitations are common with some of the other spreadsheet tools as well.

The **VMT Spreadsheet** is a manual method for estimating VMT based on trip generation rates (from local or national sources) and national survey data for trip purpose splits and trip lengths. The VMT Spreadsheet is applicable for project-scale developments or small plans in areas for which no travel demand model has been developed. It could also be used as a sketch planning tool for initial estimates of travel demand before engaging a more detailed model. Some strengths of the VMT spreadsheet are that it requires simple inputs and can provide rapid results. The simplicity of the spreadsheet is also a weakness, in that it is insensitive to smart growth development, changes in the transportation network, and urban form. Also, the spreadsheet is dependent on regional or national average data for trip lengths, which may need to be refined to represent local conditions. More advanced versions of the VMT Spreadsheet are available that further disaggregate the travel inputs, but they should only be used with the assistance of an experienced travel forecasting specialist.

The **VMT Spreadsheet with 4D Smart Growth Adjustments** expands on the VMT spreadsheet described above and incorporates the most recent body of research regarding trip generation related to smart growth developments. This tool is well suited to evaluate how land use and transportation changes impact trip generation and VMT when compared to a baseline or business-as-usual scenario (e.g., typical suburban development). The “4D” variables are a simple means of representing characteristics of smart growth. Research and field observations have shown reductions in per-capita vehicle trips and VMT in response to increases in development **d**ensity, **d**iversity, **d**esign and **d**estination patterns within a region. To date, the VMT Spreadsheet with 4D Smart Growth Adjustments is applicable only to relatively large projects (greater than 200 acres) and planning areas, but further development is underway to create a version applicable to smaller-scale projects.

A strength of the VMT Spreadsheet with 4D Smart Growth Adjustments is that it is one of the few validated techniques to account for smart growth development techniques and variability in urban form. Additionally, 4D-type adjustment techniques can be applied to other transportation planning and modeling applications to increase their functionality to analyze smart growth or infill developments. A weakness of this spreadsheet tool is that it uses data based on national survey findings and may need to be locally calibrated to provide the most accurate results for a local jurisdiction. A GIS-based land use data or a travel demand forecasting model can simplify the data collection effort for larger projects and planning areas, but these resources may not be available to some jurisdictions.

Sketch Planning Tools

The sketch planning tools are land use planning tools that incorporate some transportation data in order to rapidly assess impacts of various land use scenarios. Sketch planning tools generally incorporate a larger database of land uses and are able to account for more complex interactions than spreadsheet tools. There are many sketch planning models that have the ability to assess GHG emission levels associated with different transportation and land use scenarios. They have the advantage that once they are set up for a region, they can quickly test a variety of scenarios and present output data in a clear format that is easily understood by the public and decision makers.

The disadvantage to these tools is that the initial set up can be time consuming and require a lot of data. In addition, most sketch planning tools do not include internal models to evaluate the impacts to trip generation, trip distribution, mode choice, or route assignment of the different land use or transportation scenarios. Instead, these models rely on elasticities, rates, factors, or manual adjustments to account for changes in travel behavior, and a traffic analyst’s expertise is required to properly input these variables.

URBEMIS is one of the most user-friendly models to set up but it does not function well for large-scale, mixed-use, or smart growth plans. It works well for relatively simple projects and subarea applications. URBEMIS is primarily designed to provide emissions estimates and is discussed in greater detail under the Air Quality Tools heading in the next section.

PLACE^{3}S and **INDEX** are among the most robust sketch planning models, but they both require a considerable investment in the data collection, set-up, calibration, and data maintenance. The INDEX software is relatively expensive to purchase and maintain a license. Both PLACE^{3}S and INDEX have the ability to interface with travel demand forecasting models to provide more precise results and both also contain 4D adjustments to account for smart growth developments. PLACE^{3}S may be more accessible to local agencies since its development was supported by the energy departments of Washington, Oregon, and California; however, any customization of the software requires resources from an independent software developer. INDEX is a commercial application that runs with ArcGIS.

PLACE^{3}S and INDEX are well suited to analyzing a wide range of projects and plans. The inputs are highly flexible and both models have the ability to account for smart growth attributes through the use of the integrated 4D components. They are also attractive in areas that have a reliable database of GIS-based land use coverage data, which can be readily integrated into these systems. For areas that do not have a GIS-based land use database or for jurisdictions that lack GIS expertise, using PLACE^{3}S and INDEX would require overcoming a steep learning curve. Additionally, while the models can estimate VMT, they do not incorporate full travel demand forecasting models and do not capture the full effects of changes to the roadway/transit networks, traffic congestion, and accessibility on VMT.

<u>Travel Demand Forecasting Models</u>

Travel demand forecasting (TDF) models are developed for transportation planning purposes. They use land use data with or without socio-economic information as inputs combined with a detailed definition of the transportation system. TDF models have been used to support planning decisions for a long time and can credibly estimate large-scale travel patterns. The accuracy of the GHG estimate is further enhanced because the TDF models are sensitive to traffic congestion and predict VMT by speed. Assuming that the model is well calibrated and validated to current conditions, TDF models produce the most accurate estimate of VMT from any of the common land use-transportation analysis tools.

Of the tools described to this point, TDF models are the only ones available that can capture the GHG emissions related to new transportation infrastructure development (e.g., the mobile-source emissions related to the completion of a new road or transit service). The other tools are limited to measuring and estimating mobile-source GHG emissions that are directly related to land use development. It should be noted, however, that while TDF models can account for GHG emissions related to new or modified transportation infrastructure, research has shown that these models do not capture all the effects of these changes. In particular, increases in travel related to induced growth may be understated.

TDF models that incorporate the 4D adjustments can more accurately assess the effects of compact, smart growth, and transit-oriented developments. For example, the Puget Sound Regional Council (PSRC) TDF model is a state-of-the-practice TDF model, but it does not have a 4D component and, therefore, can overstate the GHG impacts of smart growth land use scenarios. None of the travel demand models within the state currently include the 4D adjustments, although they remain valuable tools for transportation and land use planning purposes.

As described above, one of the important strengths of TDF models is that they can more accurately estimate VMT compared to the tools previously described. This accuracy can be further enhanced with the addition of a 4D component and other advanced features (e.g., land use data with socioeconomic information, tour-based trip distribution, dynamic traffic assignment, node/intersection delay). Since TDF models have been used for a long time, their model framework is well understood and the inputs they require are generally available. The downside of TDF models is their complexity and cost. Many smaller jurisdictions may lack the staff expertise to develop a TDF model as they require a considerable amount of resources to develop, calibrate, and validate. TDF models also require fairly expensive software and regular maintenance for land use and transportation databases to produce accurate results.

Integrated Land Use Planning Models

Integrated land use planning models are tools that forecast future land use growth based on their proximity to, and interaction with, the transportation system. These land use models rely on various measures of transportation accessibility and mobility as inputs to forecast the magnitude and geographic locations of new growth.

The integrated land-use planning models have been used by major jurisdictions (including the Puget Sound area) for many years to better forecast land use development. These tools are often used to generate land use inputs for more advanced TDF models and are not directly applied to evaluate travel-related GHG emission levels of land use or transportation planning scenarios.

Several integrated land use planning models scored quite well in our evaluation, particularly **DRAM/EMPAL**, **UrbanSIM**, and **Uplan**. However, all of these models are complex, data intensive, require considerable expertise, and would not likely be used outside of a regional planning agency. Further, their use would require integration with a TDF model to estimate VMT and ultimately mobile-source GHG emissions. While the integrated land use planning models can provide high-quality land use data for input to sketch planning, travel demand forecasting, and other models, none of these tools can be used in isolation to forecast mobile-source GHG emissions.

Activity Models

Activity models are a special type of enhanced TDF model and hold the promise for a much more refined level of analysis for land use and transportation planning decisions. In general, activity models are similar to traditional TDF models, but they borrow GIS components from the sketch planning models to develop a very fine-level unit of analysis (as opposed to the large zones used in TDF models).

Activity models also incorporate more socio-economic data than typical TDF models and often use discrete choice[5] modeling to predict travel behavior. This combination tends to make activity models more sensitive to small-scale land use interactions (e.g., smart growth/transit-oriented developments), and policy changes (e.g., parking pricing, transit fairs, fuel price) that can impact travel behavior and mobile-source GHG emissions. The downside to these models is that they are extremely data intensive, are arduous to set-up and calibrate, and require input variables that are difficult to measure and predict. Activity model application can also be cumbersome because of the large datasets required. Run times are long, and thus far, the results are only marginally more informative than state-of-the-practice enhanced TDF models. Currently, there are no activity models used within the State of Washington.

Advanced Traffic Analysis Tools

Advanced traffic analysis tools like dynamic traffic assignment and traffic micro-simulation can provide a much better estimate of on-road (i.e., hot running) mobile-source GHG emissions. However, these tools require another model to generate the demand data (typically a TDF model, but other data sources can be used). These tools are also time consuming to set up and calibrate and have not been widely used

[5] Discrete choice models simulate how households make choices about travel and differ from fixed factors that are typically used in other tools.

over large areas. As traffic models, these tools are not sensitive to land use changes and must rely on other models to adjust the travel demand parameters based on changes in land uses. The project team believes that these tools have applicability for estimating mobile-source GHG emissions related to complex transportation projects (e.g., freeway widening projects, tolling projects, transit projects), but they are currently too complex for large-scale land use planning or development projects.

Air Quality Tools

This section summarizes the ability of various air quality tools to aid in analyzing transportation-related GHG emissions associated with land use development plans and projects. See **Appendix B** for additional details.

Emission Factor Sources

Emission factors for air pollutants represent the mass of emissions according to some rate of activity or consumption (or the intensity of the activity or use). GHG emission factors for mobile-sources are typically expressed in mass per distance traveled (e.g., grams per mile). Mobile-source emission factors for GHGs are available from multiple published sources, including lists of emission factors indexed by vehicle type, model year, travel speed, fuel source, and other variables. Some software programs (often referred to as models) consist of a series of lookup tables for finding a specific emission factor according to a wider set variables like fleet location, season or month, and meteorological conditions (i.e., ambient air temperature and relative humidity). These software tools can also be used to develop a composite emission factor representative of a region's vehicle fleet. By combining emissions factors and the transportation/land use planning tools described above, mobile-source GHG emissions can be estimated in a way that is sensitive to changes in land use, the transportation system, vehicle technology, and fuel source.

Two of the more useful mobile-source GHG emission factors are the EPA's **Motor Vehicle Emissions Simulator (MOVES)** and the **National Mobile Inventory Model (NMIM)**. MOVES provides GHG emission factors for on-road and off-road vehicles. Though the model is currently undergoing further development by the EPA, it can be downloaded free for use. Vehicle fleet emission factors can be developed by state, or for each county in a state, based on the pertinent vehicle fleet and local meteorological conditions. Based on the project team's analysis thus far, it is recommended that emission factors generated by MOVES be used to estimate mobile-source GHG emissions of land use development projects and plans in Washington State. MOVES can also be used to generate mobile-source emission factors for various sub regions of the State, if desired. MOVES also has the ability to forecast the emissions of future land use and transportation plans since the model forecasts future changes in fleet mix and fuel economy. NMIM is also a useful source of emission factors using the EPA's older MOBILE6 and NONROAD emissions factors, although this source will eventually be replaced by MOVES.

Accounting Software and Calculators

GHG accounting software is primarily used for recording and tracking the GHG emission levels generated by an institution or community. Most GHG accounting software is user-friendly, transparent, and used for reporting purposes.

The **Center for Clean Air Policy (CCAP) Guidebook and Calculator** consists of case studies regarding the effectiveness of various GHG reduction measures. It can be applied across the full spectrum of planning studies, however, the case study data may not apply fully to all conditions within Washington State.

The **King County SEPA GHG Emissions Worksheet** can be used to estimate the GHG emissions related to energy consumption and transportation at the project level. The user inputs the quantity (either number of dwelling units or floor area [square feet]) of up to 17 different land use types. For mobile-source emissions, it assumes a level of VMT per person based on aggregate statewide data. This VMT estimate may have some limitations as it does not account for different driving characteristics by various demographic groups and does not incorporate any reductions if a project includes smart growth development characteristics. Additionally, this tool does not account for trips that are internalized within a project or area. Thus, it is not the most accurate tool for estimating mobile-source GHG emissions for large, mixed-use, or complex projects/plans. Further investigation would be useful to determine whether these emission factors are representative of the entire State. King County is currently considering ways to improve the worksheet.

The **International Council for Local Environmental Initiatives (ICLEI) Clean Air and Climate Protection (CACP) Software** is widely used by communities across the state to estimate local GHG emissions inventories. The CACP software is essentially a tool for assembling and maintaining a community's (city or county) GHG inventory with a user-friendly interface for entering input data. It accounts for GHG emissions generated by mobile sources, areas sources, energy consumption, and waste disposal. It should be noted that ICLEI's tool is a broad GHG emissions analysis tool and CACP is meant to be the local repository for all GHG related data for local governments to build both a comprehensive government operations and a community-wide inventory. The tool has two separate functions: 1) GHG inventory analysis for all transportation within a given geographic boundary, and 2) an analytical tool that describes how GHG emissions change in response to new travel patterns, transportation systems, and land use.

ICLEI's methodology for calculating mobile-source GHG emissions is based on VMT, typically obtained from a transportation model or a separate household-based VMT estimation sheet developed by ICLEI. This software does have some limitations. For example, the ICLEI VMT estimation sheet only estimates VMT associated with residential uses. Also, the ICLEI CACP software does not enable the user to distinguish between "community VMT," (i.e., VMT generated by land uses in the community) and "through-traffic VMT" (i.e., pass-through traffic on state highways unassociated with land uses inside the local jurisdiction). Thus, for instance, if six miles of interstate freeway passed through a community, ICLEI's software would assign the GHG emissions generated by all the traffic traveling on that freeway segment to the community.

The ICLEI supplied VMT estimation spreadsheet does have a correlation between residential development density and VMT generation. However, the software's calculation of mobile-source emissions does not directly account for potential VMT reductions associated with other types of smart growth attributes (non-residential density, job-mix diversity, bicycle/pedestrian design), trip internalization, or the spatial relationship of different land use types. VMT reductions could be taken manually outside of the CACP software (using a TDF model or separate 4D smart growth adjustment), and would result in the reporting of more accurate GHG emissions from mobile sources. Overall, calculating the VMT reduction effects of smart growth development can be difficult. ICLEI encourages local governments to use travel demand tools to generate VMT and GHG emissions estimates and then to use the CACP software as a depository for this and all community emissions.

Like many of the accounting software programs, the CACP software uses nationally-derived emission rates that may not be representative of the vehicle fleet and transportation activity patterns in Washington State. Further investigation would be useful to determine whether the default emission factors could be replaced with emission factors that are more representative of transportation activity in Washington.

Note that since this evaluation was completed by the project team, ICLEI released a new version of the CACP software in 2009 that may have addressed some of the limitations described above. The CACP

2009 version of the software is also compliant with The Climate Registry (TCR) Local Government Operations Protocol.

Modeling Software

Many types of modeling software have been developed for the purpose of analyzing the relationship between multiple parameters and the effect on overall emissions. Two models previously discussed, **URBEMIS** and **INDEX**, are among the most adaptable for this purpose.

The California Air Resources Board's **Urban Emissions** model (URBan EMISsions - **URBEMIS**) estimates emissions based on the number and types of land uses as well as details about the project location, trip generation rates, and trip lengths. Strengths of URBEMIS include its ability to estimate mobile-source and area-source GHG emissions, relative simplicity for basic analyses, default parameters for more than 50 different land use types (e.g., low-density multi-family housing, elementary school, restaurant, free-standing discount superstore, office park, industrial park).

Because the URBEMIS model was designed to evaluate land use development projects in California, additional investigation is required to determine if the default emissions factor parameters are suitable for Washington State conditions. The software developer is proposing a new national version of URBEMIS with MOBILE 6 emissions factors, but the California emissions factors may be more appropriate for much of Washington State. Since the trip rates are based on standard Institute of Transportation Engineers (ITE) data, the default trip rates and lengths need further investigation, as well as the emission factors.

With regard to its estimation of mobile-source GHG emissions, URBEMIS has limited ability to account for trip internalization. Also, URBEMIS does not recognize the spatial relationship between different land use types relative to each other or relative to surrounding land uses (i.e., smart growth or mixed-use developments). Thus, URBEMIS is restricted in its ability to determine which vehicle trips are truly new to a region and cannot be used to estimate the net regional change in VMT that would result from a large development or plan. For these reasons, it would be ideal to override URBEMIS's default values for trip generation rates and trip length using estimates provided by a TDF model or by a 4D--type adjustment.

As previously described, **INDEX** is a parcel-based planning scenario model that accounts for multiple indicators, including VMT and GHG emissions, and is ideal for analyses at the plan-level (but not the project level). Unlike URBEMIS, it can be used to estimate the net regional change in VMT that would result from a proposed development. Because the model is GIS-based (i.e., data requirements are GIS coverage files), it can account for the spatial proximity of varying land use types when estimating trip generation and trip length. Additionally, INDEX has a 4D component to account for smart growth development attributes. Furthermore, any set of mobile-source emission factors could be integrated into INDEX, the ideal choice likely being state- or region-specific emission factors developed using the MOVES model.

The drawbacks of INDEX are that it would require training to operate, and the cost of each software installation is relatively expensive. INDEX is an ArcGIS extension that requires ArcView 9.2.

Protocols

Protocols are essentially instruction manuals that outline the methodologies and requirements for estimating or documenting a GHG inventory, which is often required for membership to a registry, carbon market, or for environmental assessment documentation. Several of the protocols the team evaluated provide useful guidance to practitioners, although they are not in themselves models for calculating GHG emissions. The advantage of protocols is that they provide straight-forward guidance to practitioners on measuring or estimating GHG emissions, without directly requiring a software program. Most protocols are focused at the project level and are not as useful at the plan level.

The project team recommends that a standard protocol be used if an agency wishes to develop its own set of emissions factors (as opposed to using MOVES), or if the agency would like a more simplified aggregate mobile-source emissions factor. The most widely used protocol in North America is **The Climate Registry's General Reporting Protocol (GRP)**. An alternative protocol is the **Intergovernmental Panel on Climate Change (IPCC) National Greenhouse Gas Inventory Programme (NGGIP)** guidelines and emissions factor database.

Studies

There are also multiple studies and discussion papers that provide insight about the relationship between land use, transportation planning, and regional mobile-source GHG emissions. The **California Air Pollution Control Officers Association (CAPCOA)** study provides metrics for analyzing the GHG efficiency of land use development. One metric for comparing the GHG efficiency of two land-use planning scenarios is annual GHG emissions per service population, where service population is the sum of the number of residents and jobs supported by a land use scenario. While this efficiency metric could be used to compare the efficiency of differently-sized planning alternatives, the land-use transportation planning tools discussed earlier can provide a more explicit estimation of change in VMT (and change in GHG emissions) from different land use scenarios.

The **2008 Sightline Report** provides generalized estimates of mobile-source GHG emission levels associated with the operation of each mile of newly constructed highway. However, as described earlier, a TDF model may provide a more accurate measure of the change in VMT and GHG emissions related to highway construction.

SHORT LIST OF TOOLS

Based on the screening results presented above, the list of 62 tools presented in **Appendix B** was narrowed to eight tools, listed in **Table 2**.

Table 2. Short List of Tools

Tool	Description	Typical Application
VMT Spreadsheet with emissions factors	Spreadsheet tool to estimate VMT. Combined with an emissions factor (e.g., MOVES) to estimate mobile-source GHG emissions.	Small-scale development projects and land use planning applications.
VMT Spreadsheet with 4D Smart Growth Adjustments with emissions factors	Spreadsheet tool to adjust trip generation and VMT estimates from local or national sources (e.g., Institute of Transportation Engineers) to account for smart growth and sustainable development practices. Mobile-source GHG emissions calculated using emissions factors.	Large-scale mixed-use development projects, large-scale mixed-use land use plans, and comprehensive plans.
Travel Demand Forecasting (TDF) Models with emissions factors	Common transportation planning tool that uses land use and transportation network data to estimate travel patterns. VMT output is paired with travel speeds, which leads to a more accurate estimate of mobile-source GHG emissions when combined with an emissions factor.	Large-scale development plans, comprehensive plans, transportation projects/plans. May overestimate VMT and GHG emissions from smart growth projects.
Enhanced TDF Models with emissions factors	TDF models with additional features such as socioeconomic information, advanced traffic assignment, or 4D adjustments. This tool produces the most accurate VMT estimates when	Same as TDF models, but can account for VMT and GHG reductions related to smart

	the model is validated to local conditions and combined with a detailed emissions factor like MOVES.	growth and mixed-use developments.
ICLEI CACP Software	GHG accounting software. Increased accuracy of mobile-source GHG emissions estimates are generated when VMT is supplied with a separate VMT estimation tool like those described above.	Small-scale development projects and land use plans. Difficult to properly account for GHG emissions from larger developments and plans.
URBEMIS	Air quality analysis tool with simple land use input data. More accurate mobile-source emissions estimates if emissions factors, trip generation rates, and trip lengths are validated to location conditions.	Small-scale development projects and plans.
PLACE^{3}S	Parcel-based land use/transportation planning tool with built-in smart-growth adjustments. Available web-based interface. GHG emissions estimates can be improved if travel behavior is adjusted to match location conditions and software is upgraded to incorporate emissions factors from MOVES.	Small-scale to large-scale development projects and land use plans. Particularly effective for community-based planning activities.
INDEX	Parcel-based land use/transportation planning tool with built-in smart-growth adjustments. Tool integrates with ArcGIS software. GHG emissions estimates can be improved if travel behavior is adjusted to match location conditions and software is upgraded to incorporate emissions factors from MOVES.	Small-scale to large-scale development projects and land use plans. Particularly effective for community-based planning activities. ArcGIS integration.

RELATIONSHIP OF TOOLS TO GROWTH MANAGEMENT AND ENVIRONMENTAL POLICIES

This section summarizes how the short-list of tools relates to the list of policies developed by the two committees created to guide the State's study on mobile greenhouse gas emissions: The Land Use and Climate Change (LUCC) Advisory Committee and the state's Climate Action Team (CAT).

Land Use and Climate Change (LUCC) Advisory Committee Policy Recommendations

The LUCC provided recommendations to the Department of Commerce for possible changes to the Growth Management Act and related policies. Many of the policy recommendations listed in **Table 3** support transportation and land use strategies that would reduce GHG emissions. Since the proposed GMA policies are programmatic in nature, the GHG tools cannot be used to directly analyze the GHG reductions achieved by the policies, but they could be used to evaluate planning actions proposed under the policies.

The Department of Commerce's report (formerly CTED) and the LUCC materials are located at http://www.ecy.wa.gov/climatechange/growthmgt.htm

Table 3. Relationship f Land Use And Climate Change Committee Policies To GHG Tools

Policy #	Policy	Relationship to GHG Tools
4	Better enable GMA transportation concurrency to address all modes of transportation.	This general policy statement sets the framework for evaluating multiple modes within a transportation concurrency analysis.
4a	Direct State agencies, in conjunction with other regional and local transportation entities, to provide technical, non-binding guidance on multimodal	Guidance on multimodal concurrency tools can identify how choices made to implement multimodal transportation systems can affect GHG emissions.

Policy #	Policy	Relationship to GHG Tools
	transportation systems and how multimodal considerations can be included and addressed during concurrency analysis at the local level.	
4b	Amend GMA to require local governments to provide level of service standards for all available or planned for modes of transportation and to require local governments to consider multimodal improvements or strategies in their transportation concurrency requirements.	Multi-modal levels of service policies affect the content and emphasis of local comprehensive plans. A multi-modal focus is likely to result in transportation plans that invest in a variety of travel modes. The projects contained in these plans can be evaluated using the more sophisticated transportation planning tools to estimate VMT and other traffic metrics used by the GHG emissions tools. GHG emissions would vary according to details in the multimodal plans.
5a	Require State agencies to provide technical assistance to local governments that voluntarily choose to use various developer incentives to encourage compact development	Compact development patterns have been shown to produce lower vehicle-miles of travel (VMT) and GHG emissions. The degree of these reductions depends on the specific incentives offered by a local government to encourage the compact development. (Note: This relationship also applies to LUCC Policy Recommendation 5b, which relates to the use of financing tools to encourage compact development.)
6a	Support the prioritization of existing infrastructure funds to areas promoting development and transportation choices that support the reduction of greenhouse gas emissions and dependence on foreign oil.	This policy focuses on existing transportation investment funds for projects supporting GHG reductions. The resulting projects could be evaluated with the more sophisticated transportation planning tools to estimate VMT and related inputs that feed into GHG Emissions tools. The GHG emissions would vary according to the specific content of the investment plans. The effects of potentially diverting existing funds from rural or slower-growing areas could not be identified.
6b	Support the prioritization of new infrastructure funds to areas promoting development and transportation choices that support the reduction of greenhouse gas emissions and dependence on Foreign oil.	This policy focuses new transportation investments on projects that would result in GHG reductions. The resulting projects could be evaluated using the transportation planning tools to estimate VMT and other traffic metrics used to estimate GHG emissions in the GHG emissions tools. GHG emissions would vary according to the details of the investment plans. Existing funds would continue to be allocated to priority projects contained in current transportation plans.
7	Support development of a Transfer of Development Rights (TDR) program.	This policy encourages compact development in designated areas (e.g., urban centers, infill sites) by transferring the development rights from natural resource or rural lands. The resulting development patterns could be evaluated using the land use and transportation planning tools to estimate VMT and other traffic metrics used by the GHG emissions tools. Note that not all of the land use and transportation tools are sensitive to the unique trip generation characteristics of high-density, mixed-use developments. The GHG emissions would vary according to the location and details of the compact development.

CLIMATE ACTION TEAM POLICY RECOMMENDATIONS

The 2008 Climate Action Team (CAT) was tasked with transforming the comprehensive recommendations developed in 2007 into a relatively small number of focused, refined, and effective set of actions that the Governor and the Washington Legislature can implement in order to take the critical next steps to address climate change.

The 2008 CAT was asked to focus on developing specific opportunities for reducing GHGs, continuing its innovative approach that builds upon the strengths of the State, and to advise on (and, where appropriate, reinforce) local, regional, and national emerging efforts.

The Transportation Implementation Working Group (IWG) of the CAT examined the ESSHB 2815 requirements regarding the “most promising” GHG reduction strategies and VMT reduction strategies for transportation. Many of the CAT policy recommendations are directly related to the transportation and land use strategies examined in the current study. **Table 4** summarizes the relationship between the CAT policy recommendations and the GHG analysis tools described in this report.

The State of Washington’s Climate Action Team’s 2008 report, as well as related materials is available at http://www.ecy.wa.gov/climatechange/2008CAT_overview.htm

Table 4. Relationship of Climate Action Team (CAT) Policies to GHG Tools

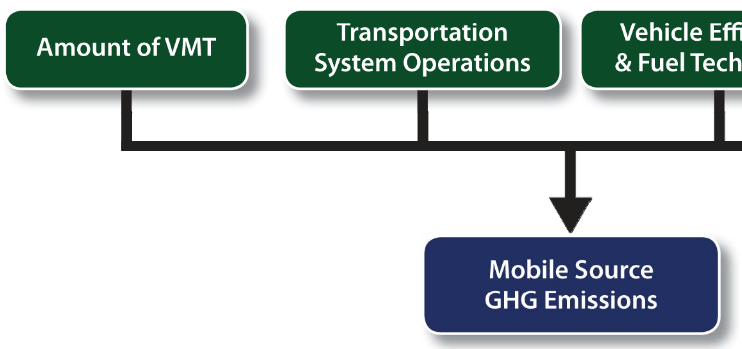
Policy #	Policy	Relationship to GHG Tools
2	Encourage compact and transit-oriented development	Compact and Transit Oriented developments (CTODs) have demonstrated reductions in VMT and GHGs based on their density, infrastructure and amenities. CTODs can be analyzed using the GHG tools that are sensitive to CTOD development characteristics (i.e., those tools with a 4D component).
2a	Housing and employment density	Increased housing and employment density is one of the primary land use factors that results in VMT and GHG reductions. This factor can be measured by several of the GHG tools that have a 4D component.
2b	Parking incentives and management	Parking strategies such as parking maximums, car-sharing, parking price, and shared parking can be analyzed with only the most advanced GHG tools (e.g., enhanced TDF models). These strategies primarily affect mode split by encouraging fewer auto trips and increasing the use of alternative modes. The specific impacts on GHG emissions will vary according to the parking strategies being employed.
2c	Bicycle and Pedestrian Accessibility	Policies that encourage bicycle travel and pedestrian accessibility can directly reduce VMT and GHG emissions. These reductions can be estimated using the GHG tools that can account for smart growth development characteristics.
2d	Urban Brownfield development	Policies to redevelop Brownfields are likely to result in more compact mixed-use and transit-oriented developments. To this extent, the resulting development patterns can be analyzed using many of the GHG tools that are sensitive to smart growth development characteristics.
2e	Transportation Concurrency	Same as LUCC Policy #4. See Table 3.
3	Use GHG/VMT outcomes as criteria for funding allocation and pursue new revenue sources to support transportation choices. Align investments and operations with achievement of the VMT and GHG reductions of ESSHB 2815.	The GHG Tools can help identify effects of transportation and land use actions on VMT and associated GHG emissions levels in different geographic areas. These metrics could be used to prioritize funding.
4	Use transportation pricing to reduce per capita-VMT and GHG emissions.	Transportation pricing can substantially affect VMT and GHG levels. Accurately estimating the effects of pricing requires the use of the more sophisticated analysis tools (e.g., enhanced TDF models). The reductions from transportation pricing would vary considerably based on the level (e.g., toll cost) and geographic extent of the transportation pricing program.
5	Pursue non-VMT actions to reduce GHG emissions from the transportation sector, including rail use, diesel engine improvements, transportation systems management, vehicle electrification, and low carbon fuel standards.	These policies are not land use or transportation actions that are typically enforced by local agencies. However, the GHG tools that incorporate detailed emissions factors (e.g., MOVES) can assess some of the effects of these strategies.

Policy #	Policy	Relationship to GHG Tools
5a	Improvements to freight railroads and intercity passenger railroads.	The GHG tools cannot estimate the direct GHG emissions from railroad activity. However, the more sophisticated tools (e.g., travel demand models) can estimate the mode shift to passenger rail and the associated reduction in automobile GHG emissions. None of the existing tools can quantify improvements to freight railroads.
5b	Diesel engine emission reductions	Some GHG tools (e.g., those with the MOVES emissions factors) can estimate the GHG reductions associated with implementation of more fuel-efficient diesel engines into a vehicle fleet.
5c	Transportation System Management	Some of the more sophisticated GHG tools (e.g., travel demand models) can estimate the inputs to the MOVES model and are able to quantify benefits associated with transportation system management.
5d	Vehicle electrification	Some GHG tools can estimate the reduction in “tailpipe” GHG emissions associated with incorporation of electric vehicles into a region’s vehicle fleet; however, none of the tools can perform a comprehensive life-cycle analysis that considers how the electricity was produced.
5e	Low carbon fuel standard	A low-carbon fuel standard addresses the GHG emissions associated with the full life-cycle of automotive fuels, including the production pathway of each fuel type. The analysis tools only analyze “tail pipe” emissions associated with vehicle travel activity.

CHAPTER 3. MOBILE SOURCE GHG REDUCTION STRATEGIES

As described in Chapter 1, the Department of Commerce is charged with identifying strategies that can reduce GHG emissions. The majority of mobile-source GHG emissions in Washington State are generated by automobiles and light trucks. Mobile-source GHG emissions are largely determined by the level of VMT, how well the transportation system operates, how efficient the vehicle is, and what types of fuels are being used (e.g., gasoline, ethanol, hydrogen, electricity). **Figure 3** shows this relationship.

Figure 3. Factors Affecting Mobile Source GHG Emissions



This chapter describes strategies to reduce mobile-source GHG emissions by reducing VMT, improving transportation system operations, or by increasing vehicle efficiency and advancing fuel technology. As discussed later, some strategies can only be implemented at the federal level. Therefore, this report focuses on how well the short list of tools identified in this report can evaluate the strategies set at the local and state levels. In addition, this chapter includes a discussion of each tool's ability to evaluate non-mobile GHG emissions.

STRATEGIES TO REDUCE VMT AND IMPROVE TRANSPORTATION SYSTEM OPERATIONS

VMT reduction and transportation system improvement strategies are attractive ways to reduce mobile-source GHG emissions because many of these strategies can be incorporated into city and county comprehensive plans. Some examples are provided below.

VMT Reduction Strategies

Strategies to reduce VMT can be achieved through land use-based or transportation-based approaches.

<u>Land Use-Based Strategies</u>

Land use-based VMT reduction strategies make it more convenient for residents and employees to travel by foot or bike by moving residential, retail, and employment uses closer together. Land use-based strategies also increase the attractiveness of high occupancy vehicles and transit by increasing densities around transit stations and employment centers. Several common land use-based strategies are listed below:

- Mixed-use developments: Projects that integrate residential and commercial development around a pedestrian-oriented design. Mixed-use developments can be vertical (e.g., residential/office with ground floor retail) or horizontal (e.g., street fronting retail with residential behind).
- Transit-oriented developments: Projects or districts that concentrate dense nodes of mixed-use development at major transit stations (bus or rail).
- Improved jobs/housing balance: A strategy that seeks to better match residences and employment centers within a city or region.

Transportation-Based Strategies

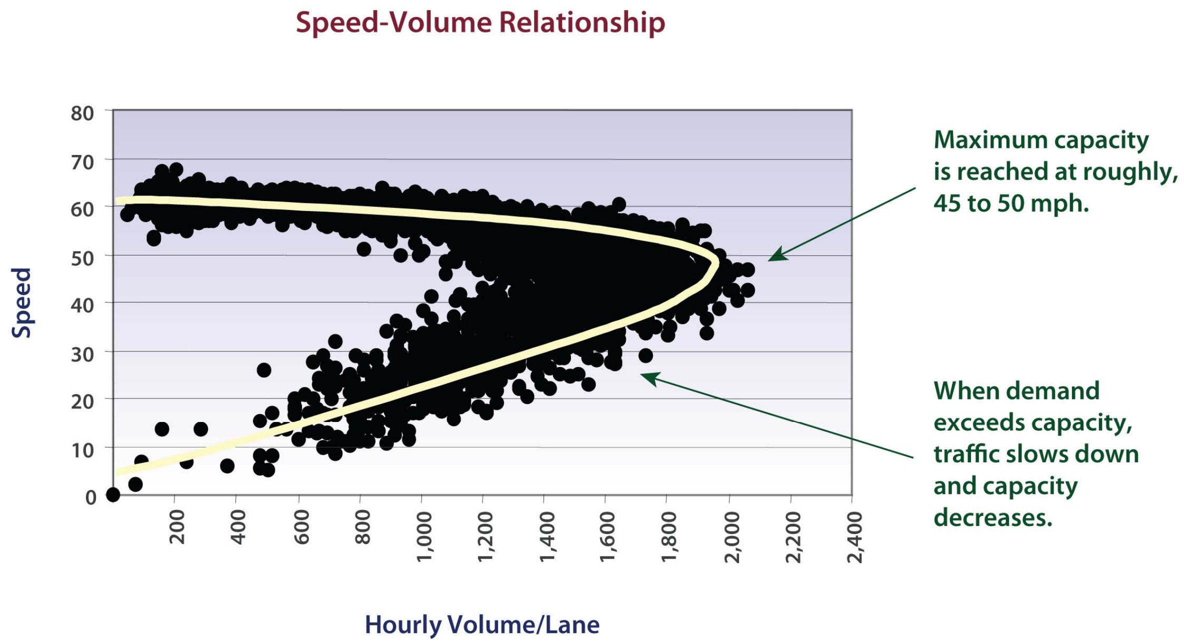
Transportation-based strategies reduce VMT by increasing the attractiveness of alternative modes of travel:

- Improved bicycle and pedestrian design: This strategy encourages bicycle and pedestrian travel by improving the design of the transportation system with these modes in mind. Examples include construction of bike lanes, sidewalk gap closure projects, introducing new development standards to minimize block lengths, and requirements for pedestrian and bicycle access easements in new developments. Many ”complete street” programs incorporate these design features.
- Transit system enhancements and expansion: Transit improvements can include operational improvements like decreased headways, and new transit-only lanes, system expansion to attract new riders, or customer service improvements like real-time arrival information or wireless internet access.
- Parking management districts: Parking management districts can discourage auto use through a variety of strategies including “decoupling” of parking costs from rents/prices, preferential parking programs for rideshare participants, or parking surcharges for transit, bicycle, or pedestrian improvements.

Transportation System Operations Strategies

Transportation system operations strategies reduce mobile source GHG reductions by optimizing the performance of the transportation system. Travel speeds are substantially affected by traffic volumes and the resulting congestion on the roadway system. **Figure 4** illustrates how travel speeds quickly deteriorate as volumes increase beyond the capacity of the roadway. On freeways, the optimal speed/volume relationship occurs at approximately 45 to 50 mph range.

Figure 4. Speed/Volume Curve



Source: Adapted from Washington State Department of Transportation (http://www.wsdot.wa.gov/NR/rdonlyres/BE788045-A653-4716-ACB2-5D78B4AA6F59/0/GrayNotebookSep08.pdf#page=50)

As shown in **Figure 5**, GHG emissions from vehicles are also minimized when vehicles operate within a range of maximum efficiency around 45 miles per hour (MPH). Reducing the amount of low-speed travel associated with stop-and-go conditions generally leads to the largest reductions in mobile source GHG emissions that can be achieved through better management of transportation systems operations.

The following strategies are ways to improve the operations of the transportation system:

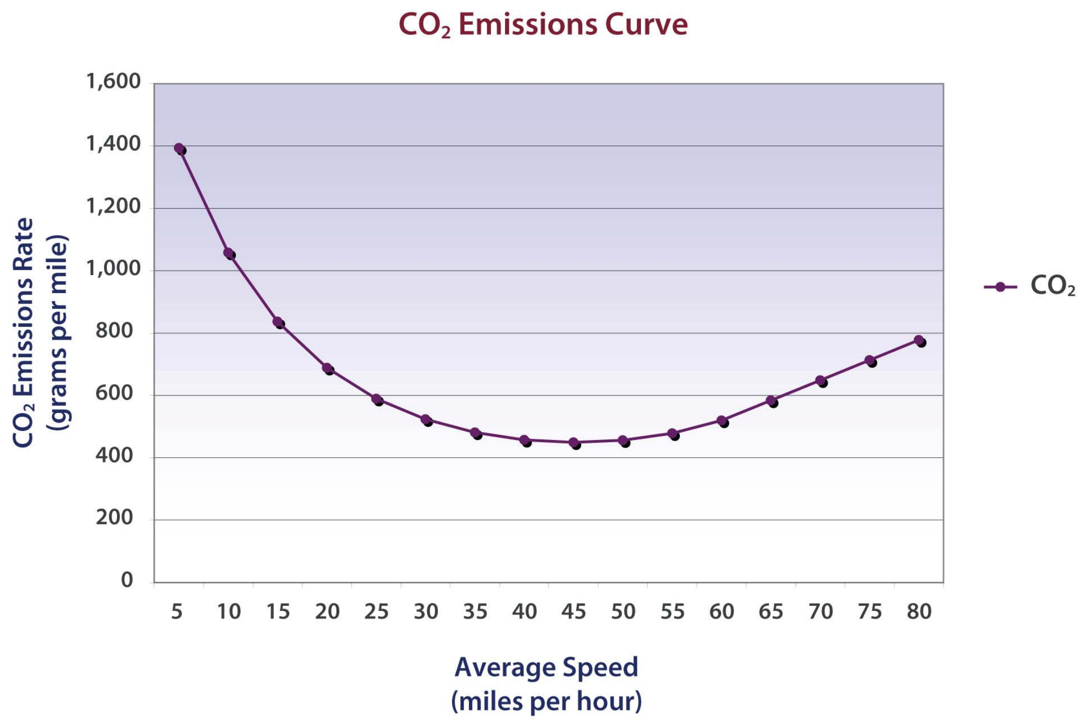
- Traffic control optimization: This strategy improves the efficiency of the transportation system by minimizing the idling, stops, and hard acceleration associated with traffic signals and stop signs. This strategy focuses on optimizing traffic control devices through traffic signal coordination and strategic installation of roundabouts.

- Congestion management: This strategy aims to keep traffic speeds near the range of maximum efficiency to minimize GHG emissions. Some examples of speed management strategies include ramp metering, variable speed limits, increased speed limit enforcement, flexible work schedules, and enhanced intelligent transportation systems (ITS) infrastructure.

Roadway Tolling Strategies

Roadway tolling strategies can leverage elements of VMT reduction and improved transportation system operations described above. In general, for tolling strategies to be effective at reducing mobile-source GHG emissions, the tolls must be set at a level high enough so that the congestion relief benefits do not encourage additional vehicle trips (a phenomenon known as induced demand). Tolling strategies can be

Figure 5. Relationship between Vehicle Speed and GHG Emissions per Mile



implemented across a range of areas, from bridges to corridors to entire cities. In general, tolling strategies will be more effective at reducing mobile-source GHG emissions when established over larger areas. Two examples of tolling strategies are described below:

- HOT Lanes: HOT, or "high-occupancy toll" lanes are carpool lanes that are also available to single occupant vehicles who pay a toll. Typically, tolls are set to maintain free flowing conditions in the HOT lane. State Route 167 between Renton and Auburn is an example of a HOT lane in Washington State. HOT lanes can reduce GHG emissions by encouraging carpooling and allowing some single-occupant vehicles to pay their way out of congestion and operate at a more efficient speed. However, if priced too low, HOT lanes can also lead to induced demand, which can offset the reductions in GHG emissions related to reduced congestion.

- Cordon Tolls: This strategy charges a toll to vehicles that cross a cordon. By increasing the cost of vehicle travel, alternative modes become more attractive and traffic levels within the cordon tend to decrease, which improves the traffic operations efficiency and reduces GHG emissions. This strategy is currently employed in many European and Asian cities and is being considered in New York and San Francisco.

GHG REDUCTIONS ASSOCIATED WITH STRATEGIES

Table 5 presents the range of GHG reductions that can be expected by implementing the VMT reduction and transportation system operations strategies described in the previous section. Note that the GHG reductions presented in the table range from a typical implementation to a best-practice implementation of the strategies. In general, there are diminishing returns when implementing multiple strategies so the GHG reductions for multiple strategies do not necessarily add together.

Table 5. Mobile Source GHG Reduction Estimates

Strategy	GHG Reduction Range	Notes
Land Use-Based VMT Reduction Strategies		
Transit Oriented Development	5-44%	Reduction compared to business-as-usual development. Greater reduction associated with higher-density projects next to high quality transit service. Source: (1)
Mixed-use Development	5-35%	Reduction compared to business-as-usual development. Greater reduction associated with higher densities, better mix of land use, and a central location. Source: (1)
Improved Jobs/Housing Balance	2-15%	Reduction compared to business-as-usual development. Source: (2)
Transportation-Based VMT Reduction Strategies		
Improved Bicycle and Pedestrian Design	0-6%	Reduction compared to typical suburban street. Source: (2)
Transit System Enhancements and Expansion	2-10%	Reduction assuming a doubling in transit revenue-miles. Source: (1)
Parking Management Districts	2-20%	Greater reduction associated with combination of parking strategies and higher fees. Source (3,4)
Transportation System Operations Improvement Strategies		
Traffic Control Optimization	5-15%	Reduction based on a 5 mile per hour increase in average speed (assuming congested conditions with speeds less than 45 MPH). See **Appendix C** for detailed calculations. Source (5)
Congestion Management	5-20%	Reductions based on a 5 MPH improvement in freeway and arterial speeds when compared to the minimal emissions generated at 45 MPH. Freeway speed assumed to decrease by 5 MPH and arterial speed assumed to increase by 5 MPH (assuming arterial speeds less than 45 MPH). Source (5)
Roadway Tolling Strategies		
HOT Lanes	0-6%	Greater benefit with larger-scale implementation. Toll must be set to discourage induced travel. Source (3)
Cordon Tolls	5-25%	Greater benefit with larger-scale implementation. Source (3)

Sources:

(1) Ewing, R., et al. *Growing Cooler*. Washington D.C. Urban Land Institute, 2008.
(2) U.S. EPA. "Index 4D Method: A Quick Response Method of Estimating Travel Impacts from Land Use Changes." Washington D.C., 2001.
(3) California Air Resources Board. "Can Transportation Pricing Strategies Be Used for Reducing Emissions?" June 1998. http://www.arb.ca.gov/research/resnotes/notes/98-1.htm
(4) Puget Sound Regional Council. "Congestion Management Strategies." http://psrc.org/projects/cms/strategies/strategies-p4.htm
(5) Calculations performed by Fehr & Peers; Emissions Factors from EMFAC 2007, V2.3 November 1, 2006. Provided by Jeff Long, California Air Resources Board, April 2007.

VEHICLE EFFICIENCY AND FUEL TECHNOLOGY EFFECTS ON REDUCING MOBILE GHG EMISSIONS

Mobile-source GHG emissions can also be reduced by transitioning the fleet of vehicles operating in a region or community to vehicles with more GHG-efficient automotive and fuel technologies. Such automotive technologies could include gasoline- and diesel-electric hybrid engines (and "plug-in hybrids"), electric vehicles, hydrogen fuel cell vehicles, as well as other technologies that increase the fuel economy from conventional gasoline engines such as variable valve timing, cylinder deactivation, turbochargers, integrated starter/generator systems, direct fuel injection, continuously variable transmissions, and automated manual transmissions. Fuel technologies include biofuels like ethanol and biodiesel, compressed natural gas, propane, and hydrogen; however, the extent to which replacing conventional gasoline and diesel with these fuels would reduce GHG missions is dependent on how the fuels are produced. This is especially the case for biofuels, which may have higher GHG emissions per VMT depending on how the fuel was produced (e.g., cellulosic vs. grain ethanol). With sponsorship from the U.S. Department of Energy, Argonne National Laboratory has developed a model called GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) to examine the full life-cycle GHG emissions of various automotive fuels.

Trends – Air Pollution Emissions versus GHG Emissions

In general, emissions of criteria air pollutants (and precursors) and mobile source air toxics (MSAT) have been trending downward over the last 30 years. This trend is primarily due to the development and implementation of regulations over the past several decades which mandate better air pollution control devices, inspection and maintenance programs, and reformulated fuels. The changes brought about by these regulations have outpaced increases in population and VMT.

However, though some criteria air pollutant and MSAT-focused regulations have as a secondary benefit reduced GHG emissions, GHG specific legislation is now just currently being developed. Consequently, unlike criteria air pollutants and MSATs, GHGs emissions are trending upward under business as usual conditions.

Vehicle and fuel technology improvements are not examined in this analysis due to the limited influence that local land use and transportation planning can have on the public's selection of vehicle and fuel types or establishing a local low-carbon fuel standard. While the State of Washington and local jurisdictions could attempt to implement policies that encourage the public to make GHG-efficient choices regarding the types of vehicles and fuels they use (e.g., rebates, preferential parking for alternative vehicles, biofuel fueling stations), the participation rates associated with such programs and associated GHG reductions have not been substantiated. Local governments would likely have more success in encouraging sustainable development practices like smart growth, mixed-use developments and transit-oriented developments and providing financial incentives for home energy efficiency improvements that could result in the reduction of stationary source GHG emissions.

ABILITY OF TOOLS TO ADDRESS GHG REDUCTION STRATEGIES

Table 6 summarizes how well the tools analyze the VMT reduction and the transportation system operations improvement strategies. **Appendix D** provides a more complete tabulation of the strategies and tools. While the vehicle and fuel technology strategies are not being evaluated, it should be noted that tools, which include the MOVES air quality model, will be able to account for some of the GHG reduction benefits associated with these types of strategies. More aggregate emissions factors that do not have the ability to adjust the mix of vehicles in the fleet or the types of fuel consumed are unable to account for vehicle and fuel technology improvement strategies.

The findings presented in Table 6 indicate that the relatively simple and easy to use URBEMIS tool is not well suited on its own to evaluate the mobile source GHG impacts related to the strategies. The sensitivity can be increased by replacing URBEMIS' built-in trip generation and VMT estimate with one created by a separate transportation model. However, even more sensitivity can be gained by using a separate transportation model combined with an aggregate emissions factor. Overall, the more complex and data-intensive tools are able to account for more of the impacts associated with the GHG reduction strategies.

ABILITY OF TOOLS TO EVALUATE GHG EMISSIONS FROM NON-MOBILE SOURCES

In addition to estimating GHG emissions from mobile sources, some of the analysis tools can be used to quantify GHG emissions from non-mobile sources. Non-mobile sources of GHG emissions are important features of a community's carbon footprint. However, non-mobile sources are typically not factored into the elements of a jurisdiction's Comprehensive Plan.

URBEMIS can estimate GHG emissions from "area sources" associated with the operation of multiple types of residential, commercial, and industrial land uses. The area sources within URBEMIS include emissions from on-site natural gas fuel combustion for space and water heating; emissions generated by fireplaces and wood stoves; and emissions from the use of landscape maintenance equipment (e.g., lawn mowers). In addition to having default GHG emission factors for these area sources, URBEMIS makes assumptions about the quantities of fuel (i.e., natural gas, wood, gasoline) used by the area sources for the different land use types, and users can override these input parameters if desired. URBEMIS does not, however, estimate the emissions associated with stationary point sources (e.g. related to electricity consumption from the electric grid).

In order to estimate GHG levels generated by area sources using ICLEI's CACP software, PLACE^{3}S, or the INDEX model, users must provide data about the amount of fuel consumed by these sources. The tools listed above do not include any default assumptions about the amount of fuel consumed for space and water heating, fireplaces or wood stoves, or landscape maintenance activity for different land use types. These fuel consumption rates would have to be determined by the users of these models. The other tools, VMT Spreadsheet, VMT Spreadsheet with 4D Smart Growth Adjustments, and TDF Models (both standard and enhanced) do not have the ability to account for non-mobile GHG sources.

Table 6. Ability of Tools To Analyze GHG Reduction Strategies

Tool		Land Use-Based VMT Reduction Strategies	Transportation-Based VMT Reduction Strategies	Transportation System Operations Improvement Strategies
VMT Spreadsheet with Emissions Factors				
VMT Spreadsheet	National Average Emissions Factors	◔	○	○
	Aggregate MOVES Emissions Factors	◔	○	○
VMT Spreadsheet with 4D Smart Growth Adjustments with Emissions Factors				
VMT Spreadsheet with 4D Adjustments	National Average Emissions Factors	◕	◔	○
	Aggregate MOVES Emissions Factors	◕	◔	○
Travel Demand Forecasting (TDF) Model with Emissions Factors				
TDF Model	National Average Emissions Factors	◐	◐	◔
	Aggregate MOVES Emissions Factors	◐	◐	◔
	Detailed MOVES Emissions Factors	◐	◐	◐
Advanced TDF Model with Emissions Factors				
Enhanced Advanced TDF Model	National Average Emissions Factors	●	◕	◐
	Aggregate MOVES Emissions Factors	●	◕	◐
	Detailed MOVES Emissions Factors	●	◕	◕
URBEMIS Models				
URBEMIS Software		○	○	○
VMT Spreadsheet	URBEMIS Emissions Factors	◔	○	○
VMT Spreadsheet with 4D Adjustments		◔	○	○
TDF Model		◐	◐	◔
Advanced TDF Model		●	◕	◐
ICLEI CACP Models				
ICLEI CACP Software		◔	◔	○
VMT Spreadsheet	ICLEI CACP Emissions Factors	◔	◔	○
VMT Spreadsheet with 4D Adjustments		◕	◔	○
TDF Model		◐	◐	◔
Advanced TDF Model		●	◕	◐

Tool	**Land Use-Based VMT Reduction Strategies**	**Transportation-Based VMT Reduction Strategies**	**Transportation System Operations Improvement Strategies**
PLACE³S Model			
PLACE³S Software	◕	◐	○
INDEX Model			
INDEX Software	◕	◐	○

Legend:

- Tool Name
- VMT Estimation Component
- GHG Estimation Component
- Combined VMT/GHG Estimation Component

Tool Ability to Assess Strategies

Not able to evaluate strategy	○
Minimal ability to evaluate strategy	◔
Fair ability to evaluate strategy	◐
Good ability to evaluate strategy	◕
Excellent ability to evaluate strategy	●

CHAPTER 4. SELECTING THE RIGHT TOOL

The previous chapters described how the short list of greenhouse gas (GHG) analysis tools was developed from an initial set of more than 60 tools and how those tools account for various GHG reduction strategies. While the earlier information provided helps to narrow down the long list of available tools, this chapter provides guidance to agencies when selecting a GHG tool for a particular task.

CONSIDERATIONS WHEN SELECTING A TOOL

Selecting the appropriate GHG tool for a community can be a challenge. However, the selection of the right GHG analysis tool can be streamlined by answering the following two questions:

- What is the purpose of the analysis?
- What are the resources and/or time availability of agency staff?

The following sections summarize how these questions may be addressed.

What is the Purpose of the Analysis?

A community should select a GHG tool based on its level of interest in estimating GHG impacts, the level of confidence and accuracy it wants in the estimation results, and the level of scrutiny expected from the public.

- *Level of Detail* – How much detail is the community seeking to provide regarding GHG impacts? Communities that have a high interest in GHG emissions may opt to use a more sophisticated and comprehensive tool.
- *Level of Detail* - Each of the tools predicts GHG emissions at different levels of detail according to VMT forecast sensitivity and adaptability of the emissions factors to local conditions.
- *Level of Scrutiny* - Certain environmental studies will require substantial scrutiny (and legal defensibility) requiring the use of more sophisticated tools.

Responses to these questions may be a function of the size and location of a community within the State. Larger urban areas are more likely to have a strong interest in GHG analysis and require a greater degree of confidence in the results, due to the level of scrutiny in their transportation plans. However, many smaller agencies may have a high level of interest in GHG and desire more sophisticated analyses for certain types of planning applications.

What are the Resources and/or Time Availability?

A community must consider the resources it has available to conduct a GHG analysis. Resources include staff availability/expertise, analysis tools and software, and/or consultant funds. Smaller agencies may need to trade off their desired level of accuracy of the GHG estimations with their ability to conduct the studies in-house or with a limited consultant budget. Larger agencies that possess more resources may face staff time constraints, depending on the priorities given to the GHG analysis. The schedule for completion of the analysis is also a potential constraint that could affect tool selection and application. Many of the more sophisticated tools must first be set up, calibrated, and validated. After these tools are ready, the results require interpretation and synthesis and may require additional time to use than simpler, less robust tools. The more sophisticated GHG tools also require access to other software, notably a travel demand forecasting (TDF) model or reliable geographic information systems (GIS) databases.

The following diagrams provide examples of how the factors described above can influence the choice of a GHG tool. The most accurate results can be achieved if a TDF model is available, particularly when analyzing a transportation infrastructure project; however, there are also options available if a TDF model is not available.

For areas with a TDF model available, **Figure 6** presents an example decision tree for selecting an appropriate tool. The decision tree shows that if the agency needs to perform a relatively simple analysis for a non-controversial project or plan, there are several options available. For example, if the TDF model produces reasonable trip generation and traffic volume estimates near the project/plan area, then it would be a good choice for analyzing GHG emissions. If the TDF model is not well suited to the area, then a relatively simple tool like the VMT spreadsheet or URBEMIS could also work well.

For more complex or controversial projects, the decision tree points to other tools. For example, if the project or plan involves a smart growth or mixed-use element, yet there is not much staff time or expertise available, then the VMT Spreadsheet with 4D Smart Growth Adjustments would be an appropriate tool. If more time or expertise is available, then a more complex tool like an enhanced TDF model will provide the most accurate and robust results. PLACE[3]S and INDEX are good choices if the analysis is done in a community meeting or commission workshop setting, since these tools have a more interactive user interface and graphical output.

Figure 6. Example Decision Tree for Selecting Tools – Areas with a Travel Demand Forecasting Model

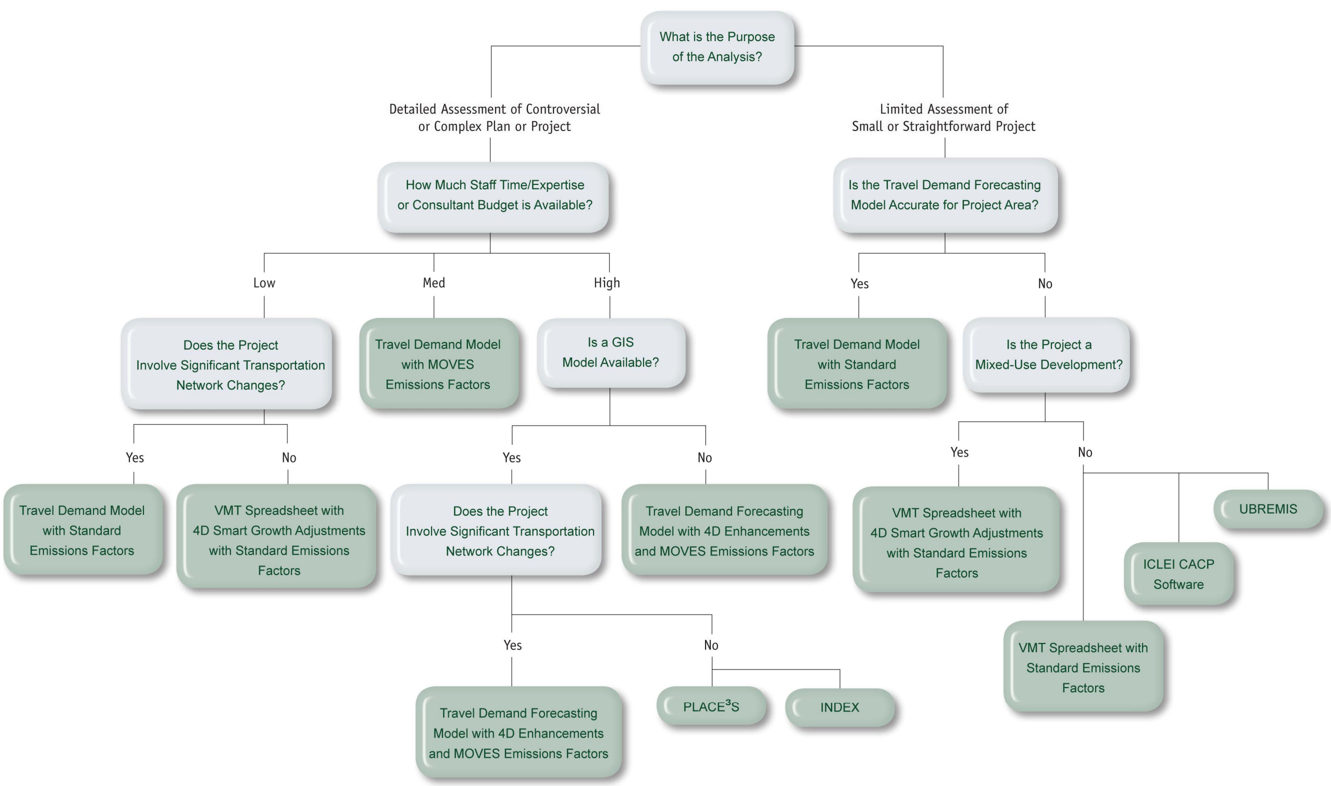
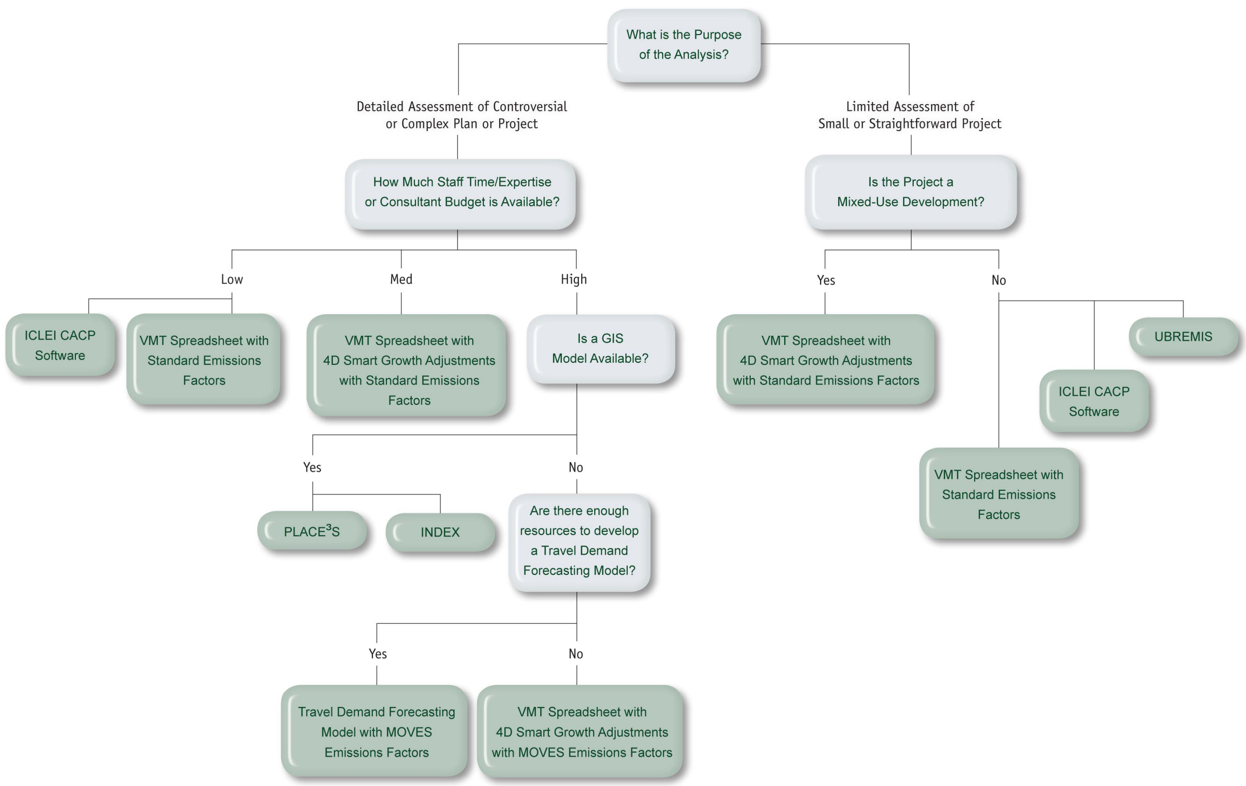


Figure 7 presents an example decision tree for a jurisdiction that lacks a TDF model. For simple and/or non-controversial projects, an agency may opt to use URBEMIS for a single-use project or the VMT Spreadsheet with 4D Smart Growth Adjustments for a mixed-use plan.

For more complex or controversial projects, the decision tree again leads to more complex tools. If the jurisdiction has good GIS data, then PLACE^{3}S or INDEX are good choices. If GIS tools are not an option, another choice is the VMT Spreadsheet with 4D Smart Growth Adjustments along with the MOVES emissions factors.

Figure 7. Example Decision Tree for Selecting Tools – Areas without a Travel Demand Forecasting Model



CRITERIA FOR EVALUATING GHG TOOLS

The previous section described a broad set of considerations that jurisdictions can consider when selecting a GHG tool. However, in certain cases, the tool's performance against a more specific criterion may be an important consideration. This section describes a set of evaluation criteria identified by the project team and the Technical Review Team[6]

Sensitivity – The following criteria address the tool's sensitivity to factors that influence mobile-source GHG emissions.

[6] The Technical Review Team is comprised of representatives from CTED, other state agencies, the Association of Washington Cities, and the Washington State Association of Counties.

- Sensitivity to land use changes: Is the tool able to account for the variation in trip generation and VMT characteristics associated with different land use types? Can the tool account for trip internalization and mode shift associated with smart growth and transit-oriented development?
- Sensitivity to transportation network changes: Is the tool able to account for changes in congestion levels and induced demand effects associated with transportation network changes?
- Sensitivity to land use and transportation policies: Can the tool predict changes in VMT and GHG emissions that result from changes in land use and transportation policies (e.g., policies that encourage infill development, congestion pricing policies)?

Adaptability – The following criteria highlight the adaptability of the tool to external factors that influence mobile-source GHG emissions.

- Adaptability to different project scales: How well can the tool analyze GHG emissions from projects that range in size from a small development to a comprehensive transportation plan?
- Adaptability to Washington State conditions: How easily can the tool be adjusted to adapt to the different conditions in Washington? Regions across Washington State vary according to their climate, travel behavior, vehicle fleet, and socioeconomic characteristics. (Note that a subsequent section of this chapter discusses potential ways the tools could be modified to account for these regional variations.)

Support – The following criteria highlight the availability of support to assist agencies and jurisdictions when using a tool.

- Availability to public agencies: Is the tool readily and freely available or is the tool a costly (in terms of time and/or money) custom-built application?
- Availability of technical support: Is technical support available for the tool? Is the support costly to obtain?

Ease of Use – The following criteria highlight how easy the tool is to apply.

- Use of available data: Does the tool use readily use available data or does the input require a considerable amount of research or input parameters to use?
- Use of available hardware: Can the tool be operated with a standard desktop computer or is a high-powered work-station required?
- Annual maintenance requirements: Is the input data simple to maintain (or be maintained by a third party) or is there a substantial effort required to collect and store input data?

Other GHG Sources – While not the primary focus of this report, the following criteria address whether the tool can account for GHG emissions reductions from vehicle and fuel technology changes and non-mobile sources:

- Ability to account for changes in vehicle and fuel technologies: Can the tool quantify the GHG emissions reductions associated with advancements in vehicle or fuel technologies?
- Ability to account for non-mobile sources: Can the tool account for non-mobile source emissions associated with land use development projects?

Cost – This criterion considers the up-front cost to obtain the tool, the annual costs to maintain the license (if applicable), and the staff resources needed to run the tool.

Accuracy – This criterion concerns the accuracy of each tool's estimation of GHG emission levels for a range of simple and complex project types.

COMPARING THE TOOLS AGAINST THE CRITERIA

Table 7 summarizes how the tools compare using the criteria described above. See **Appendix E** for a detailed evaluation of each tool's performance against the individual criteria listed in the previous section.

Table 7. Comparison of GHG Tools

Tool		Sensitivity			Adaptability	Support	Ease of Use	Other GHG Sources	Cost	Accuracy
		Land Use Changes	Transportation Changes	Policy Changes						
VMT Spreadsheet with Emissions Factors										
VMT Spreadsheet	National Average Emissions Factor	◔	○	○	◑	◑	◕	○	●	○
	Aggregate MOVES Emissions Factor	◔	○	○	◑	◑	◕	◔	●	◔
VMT Spreadsheet with 4D Smart Growth Adjustments with Emissions Factors										
VMT Spreadsheet with 4D Adjustments	National Average Emissions Factor	◑	◔	◔	◑	◑	◑	○	●	◔
	Aggregate MOVES Emissions Factor	◑	◔	◔	◑	◑	◑	◔	●	◑
Travel Demand Forecasting (TDF) Model with Emissions Factors										
TDF Model	National Average Emissions Factor	◑	◕	◔	◑	◔	◑	○	◔	◑
	Aggregate MOVES Emissions Factor	◑	◕	◔	◑	◔	◑	◔	◔	◑
	Detailed MOVES Emissions Factors	◑	◕	◑	◕	◔	◔	◑	◔	◕
Enhanced TDF Model with Emissions Factors										
Enhanced TDF Model	National Average Emissions Factor	●	●	◕	◑	○	◔	○	○	◑
	Aggregate MOVES Emissions Factor	●	●	●	◕	○	○	◔	○	◕
	Detailed MOVES Emissions Factors	●	●	●	◕	○	○	◑	○	●
URBEMIS Models										
URBEMIS Software		◔	○	◑	◑	◑	●	◑	●	○

VMT Spreadsheet	URBEMIS Emissions Factors	◔	○	◑	◑	◑	◕	◑	●	◔
VMT Spreadsheet with 4D Adjustments	URBEMIS Emissions Factors	◑	◔	◑	◑	◑	◕	◑	◕	◔
TDF Model	URBEMIS Emissions Factors	◑	◑	◑	◑	◔	◑	◑	◔	◑
Enhanced TDF Model	URBEMIS Emissions Factors	●	◑	◑	◑	○	○	◑	○	◑
ICLEI CACP Models										
ICLEI CACP Software		◔	○	◔	◑	◕	◑	◑	◑	◔
VMT Spreadsheet	ICLEI CACP Emissions Factors	◔	○	◔	◑	◑	◑	◑	◑	◔
VMT Spreadsheet with 4D Adjustments	ICLEI CACP Emissions Factors	◑	◔	◔	◑	◑	◑	◑	◑	◔
TDF Model	ICLEI CACP Emissions Factors	◑	◑	◔	◑	◔	◔	◑	◔	◑
Enhanced TDF Model	ICLEI CACP Emissions Factors	●	◑	◔	◑	○	○	◑	○	◑
PLACE³S Model										
PLACE³S Software		●	◔	◕	◕	◔	◔	◑	◑	◕
INDEX Model										
INDEX Software		●	◔	◕	◕	◔	◑	◑	◔	◕

Legend:

Tool Name
VMT Estimation Component
GHG Estimation Component
Combined VMT/
GHG Estimation Component

Performance Measure:

Worse ○ ◔ ◑ ◕ ● Better

Table 7 indicates that no tool is strong across all the evaluation criteria. For example, the enhanced TDF models produce the most accurate estimates of VMT and are highly adaptable to different conditions (e.g., project scale, socioeconomic differences), but these models are expensive to develop, have onerous maintenance requirements, and require a considerable level of expertise to use. Conversely, URBEMIS is freely available, easy to use, and has low maintenance requirements, but it is not sensitive to many factors that influence trip generation. As a result, the mobile-source GHG emission levels estimated by URBEMIS are less accurate.

In the end, jurisdictions must weigh the desire to prepare a detailed, accurate estimate of mobile-source GHG emissions for a plan or project against the time and resources available. As described at the beginning of this chapter, a larger agency with a travel demand model may choose to use URBEMIS to evaluate a small non-controversial project to avoid burdening the project with a costly and lengthy GHG evaluation. Conversely, a smaller jurisdiction may opt to develop an INDEX model for a complex mixed use plan because it wants to more accurately quantify the benefits of the density, design, and diversity of the uses in the site.

ADAPTABILITY OF TOOLS TO COMMUNITY CHARACTERISTICS

One of the evaluation criteria considers a tool's ability to adapt to differing community characteristics from locations across the State. Because many of the tools rely on national data for all or part of their input assumptions, this criterion is of particular interest to some jurisdictions.

Table 8 shows that the simpler tools such as spreadsheets, URBEMIS, and the ICLEI CACP software are less adaptable to variations in community characteristics than the more complex GIS-based tools and TDF models. The reason that the simpler tools are less adaptable is two-fold. First, the more complex tools tend to be custom built for a jurisdiction and therefore contain more in the way of local data (including socioeconomic, travel behavior, fleet mix, and geographic information). The simpler tools often are often based on national average data, which may provide less accurate results for certain communities.

The second reason the simpler tools are less adaptable to various community characteristics is based on how they are structured. The more complex tools have individual components that can be modified to account for specific variations, such as population (e.g., location of senior housing facilities, areas with large households) or policies (e.g., travel demand management programs, parking management districts). The simpler tools do not have components to consider these factors.

While the simpler tools may not be as adaptable to variations in community characteristics, they may still be a good option for certain projects. As described earlier, the choice of which tool to use may boil down to the complexity of the project or plan being evaluated and the scrutiny it is likely to face. Even in unique communities with distinct travel patterns or socioeconomic characteristics, a spreadsheet tool may provide a good mobile source GHG estimate in many applications.

Table 8. Adaptability to Community Characteristics

Tool		**Geography** (coastal, mountainous)	**Population** (# of people, age distribution)	**Density** (residential and employment)	**Economic** (job types, jobs-housing balance)	**Urban Design** (walking environment, streetscape)	**Transportation** (congestion levels, transit availability, accessibility)	**Vehicle Fleet** (age, composition, fuel source)	**Regulation** (parking restrictions, TDM programs)
VMT Spreadsheet with Emissions Factors									
VMT Spreadsheet	National Average Emissions Factors	○	○	○	○	○	○	○	○
	Aggregate MOVES Emissions Factors	◕	○	○	○	○	○	◑	○
Trip Generation with 4D Adjustment Spreadsheet with Emissions Factors									
Trip Generation with 4Ds Spreadsheet	National Average Emissions Factors	○	○	◕	◕	◑	○	○	○
	Aggregate MOVES Emissions Factors	◕	○	◕	◕	◑	○	◑	○
Travel Demand Forecasting (TDF) Model with Emissions Factors									
TDF Model	National Average Emissions Factors	◔	◑	◔	◑	◔	◑	○	◔
	Aggregate MOVES Emissions Factors	●	◑	◔	◑	◔	◑	◑	◔
	Detailed MOVES Emissions Factors	●	◑	◔	◑	◔	◕	●	◔
Enhanced TDF Model with Emissions Factors									
Enhanced TDF Model	National Average Emissions Factors	◔	◕	●	●	◑	◑	○	◑
	Aggregate MOVES Emissions Factors	●	◕	●	●	◑	◑	◑	◑
	Detailed MOVES Emissions Factors	●	◕	●	●	◑	●	●	◑

ICLEI CACP Models									
ICLEI CACP Software		○	○	◔	○	○	○	◔	◔
VMT Spreadsheet	ICLEI CACP Emissions Factors	○	○	○	○	○	○	◔	◔
Trip Generation with 4Ds Spreadsheet		○	○	◕	◕	◑	○	◔	◔
TDF Model		○	◑	◔	◑	◔	◑	◔	◔
Enhanced TDF Model		○	◕	●	●	◑	◑	◔	◑
Place³s Model									
Place³s Software		◑	◑	●	◑	◕	◔	◑	◑
INDEX Model									
INDEX Software		◑	◑	●	◑	◕	◑	◑	◑

Legend:

- Tool Name (purple)
- VMT Estimation Component (light gray)
- GHG Estimation Component (medium gray)
- Combined VMT/ GHG Estimation Component (dark gray)

Performance Measure:

Worse ○ ◔ ◑ ◕ ● Better

TOOL PERFORMANCE IMPROVEMENTS FOR WASHINGTON STATE CONDITIONS

The previous sections described how well the short-listed tools are able to adapt to variations in community characteristics. This section describes the measures that can be taken to improve the tools' ability to quantify mobile source GHG emissions in Washington State. In general, all the tools can be enhanced by replacing national average input data to calculate VMT and GHG emissions with more localized data. These local data can be regional, countywide, or citywide in nature and are usually collected through a travel survey.

Transportation/Land Use Tools

In general, the VMT estimation tools can produce more accurate results when locally valid input data are used. For example, the VMT Spreadsheet will perform better when national average trip length data are replaced with trip length data collected as part of a local travel survey. Similarly, the VMT Spreadsheet with 4D Smart Growth Adjustments will perform better when local travel survey data is used to calibrate the trip generation rates and 4D elasticities.

A Local Case Study Using the GHG Tools

King County completed a project called LUTAQH (Land Use, Transportation, Air Quality and Health) study in 2005 to determine the relationships between land use patterns, air quality, transportation and health. This research provided the foundation for development of a GHG modeling tool (PLACE³S) that was calibrated for application within all of King County and tested on a case study site in White Center. The study team used the web-based version of the tool, named I-PLACE³S. I-PLACE³S analysis is conducted through a web-based map display.

The tool was tested on a small case study area in White Center in unincorporated King County - the SW 98th Street corridor[2]. The zoning regulations in the SW 98th Street corridor are being changed to increase allowable densities and allow/encourage mixed use development. I-PLACE³S was used to test how these potential changes might impact per capita GHG and air pollution for residents of the area.

Overall, the White Center case study was a successful test of the I-PLACE³S GHG tool. The analysis indicated that if the changes the County made in development regulations can spur redevelopment of the SW 98th Street corridor, they are likely to positively impact air pollution and carbon dioxide emissions. I-PLACE³S was found to be a tool that has good potential to inform King County during a number of processes – including planning, zoning, development review, transit and other transportation investments. At larger scales of analysis, such as the entire county or region, the researchers determined that I-PLACE³S could also be used in conjunction with the four-step regional travel model to capture the full interaction between land-use and transportation investments.

Land Use, Transportation, Air Quality, and Health, developed by Lawrence Frank & Co., Inc. for King County, funded from a Federal Transit Authority Grant (For a full copy of the LUTAQH final report, see www.kingcounty.gov/transportation/healthscape)

[2] I-PLACE³S Health & Climate Enhancements and Their Application in King County I-PLACE³S Development and Application FINAL REPORT. Prepared by: Lawrence Frank and Company, SACOG, and Mark Bradley, June 2009.

TDF models are typically validated to local conditions when they are built, and they tend to perform well at the local level without additional modification. However, as shown in the table above, the addition of advanced TDF model components (e.g., 4D adjustments, dynamic traffic assignment, value of time) improves the accuracy of estimates for VMT and mobile-source GHG emission.

Similar to the TDF models, the land-use components of the GIS-based tools like PLACE^{3}S and Index are usually validated to local conditions when they are set up. However, these tools tend to contain national average data on trip generation, trip length, and 4D elasticities that can be further enhanced using data from local travel surveys.

Air Quality Tools

Model runs that use the MOVES emissions factors can be performed for any state, county, or group of counties in the U.S. using default parameters for these locations in the model's database. If available, local data can be imported into the MOVES database to override default parameters including:

- Information about the local fuel supply;
- Vehicle fleet characteristics, including the mix of alternative vehicles (i.e., electric, hybrid, and natural gas) and vehicle age distribution;
- Vehicle travel speed profile;
- Types of roads used; and
- Meteorological parameters (i.e., temperature and humidity).

In addition, these parameters can be tailored for each hour of the day, and for weekdays and weekend days, if desired. Importing data about local conditions into the MOVES model requires a relatively high level of expertise about how to use the software and manage the supporting database. Note that the Puget Sound Regional Council is currently starting to employ the MOVES model to evaluate GHG emissions associated with regional land use development and transportation planning studies.

The Urban Land Use Emissions model (URBEMIS) was developed to estimate emissions generated by land use development projects in California. As part of its design, it uses default values for input parameters depending on the county or air basin in which the evaluated project or plan is located (in California). Some of these vehicle parameters could be adjusted to represent a particular county or region in Washington State. This includes the average temperature (daily high and daily low) and humidity during summer and winter (two seasons only); the average length of vehicle trips; and average vehicle speed (rather than using different speeds for each vehicle class, or a comprehensive speed profile). It also includes the mix of vehicle classes within the fleet mix. However, the list of 13 different gasoline- and diesel-engine vehicle classes listed in URBEMIS does not include any alternative vehicle types (i.e., electric, hybrid, or natural gas). The default assumptions for the fleet mix used by URBEMIS are based on car registration data collected by the California Department of Motor Vehicles. It would not be possible to override the GHG emission factors used by URBEMIS without changing the source code of the software; however, the project team is further investigating how the GHG emission factors were developed and whether they would also be applicable to vehicle fleets in Washington State. Generally, the URBEMIS model is simpler to use than the MOVES model, but it cannot be as readily tailored to regional conditions.

The emission rates used in the ICLEI CACP software could also be changed to adapt to regional conditions throughout Washington State. These rates can be provided in mass per mile of travel (e.g., grams per mile), which can be altered for different vehicle classes; or mass per volume of fuel consumed (e.g. grams per gallon), which can be provided for different automotive fuel types (e.g., gasoline, diesel, natural gas, ethanol, biodiesel) and for electric vehicles.

The PLACE^{3}S and INDEX models can be modified in multiple ways. This includes the GHG emission factors that can be broken down by vehicle class or speed class. However, these types of changes would require alteration of the source code, which is proprietary and would need to be performed by the developers.

CHAPTER 5. CONCLUDING THOUGHTS

In an effort to address concerns over global climate change and dependence on foreign oil, the Washington State Legislature has passed a law defining a set of GHG emissions reduction targets. In setting these targets the Legislature recognized that the transportation sector is the largest source of GHG emissions in the State and that there is a strong relationship between land use, transportation, and GHG emissions.

This report supports Washington's GHG emissions reductions targets by providing jurisdictions with information about tools that can estimate and analyze mobile-source GHG emissions (primarily from automobiles and light trucks). In addition, this report outlines strategies that jurisdictions can take to reduce GHG emissions related to land use and transportation. The report evaluated over 60 land use planning, transportation planning, and air quality tools in the spring of 2009 to develop a short list of tools that have the most promise of being widely used to evaluate GHG emissions. The short-listed tools were evaluated against a set of criteria that measured aspects like sensitivity to land use and transportation changes, each tool's user friendliness, and the tool's ability to accurately estimate GHG emissions.

This chapter summarizes the findings, and provides recommendations and next steps for Washington State's effort to quantify and reduce GHG emissions.

KEY FINDINGS

A primary focus of this report is to evaluate various tools' ability to estimate and analyze GHG emissions, primarily from mobile sources. Below are key findings related to the GHG tool evaluation.

- Some local and regional jurisdictions are voluntarily taking a variety of approaches when evaluating GHG emissions and not all agencies are quantifying the emissions related to transportation and land use.
- Of the large number of tools available to evaluate GHG emissions, only some of the tools have enough detail to adequately account for the land use-transportation-GHG emissions connection. The tools with the most promise in accounting for this link were short-listed.
- Several of the tools on the short list provide either estimates of travel behavior or greenhouse gas emissions, but not both. Use of these tools would involve blending transportation-land use tool that outputs a VMT estimate with a GHG emissions factor tool.
- Other tools on the short list are "all-in-one" tools that consider land use quantities, travel behavior, and GHG emissions factors. However, in several cases, these tools can be enhanced by adding details from other transportation VMT estimation tools. In all cases, the accuracy of these tools can be increased by replacing national average data with more localized socioeconomic, travel behavior, and fleet mix data.
- Several tools have the ability to quantify non-mobile GHG emissions.
- The tools on the short list have the ability to quantify GHG emissions from different scales of application (e.g., small projects to comprehensive plans). Some tools like PLACE^{3}S, INDEX, and validated TDF models can estimate GHG emissions across all project scales, while others like URBEMIS are better suited to smaller applications.

- The accuracy of GHG emissions estimates increases based on the complexity and sophistication of the tool. A simple VMT estimation spreadsheet can be applied by any jurisdiction to estimate order-of-magnitude GHG emissions. More sophisticated applications require development of a travel demand forecasting model and/or acquisition of proprietary software.

- As agencies select an appropriate tool to evaluate the GHG emissions for a particular application, consideration should be made about the available resources, the complexity of the project/plan, and the level of scrutiny the project/plan is likely to face. Jurisdictions may utilize multiple tools to evaluate GHG emissions based on resource availability and the level of confidence required.

- Jurisdictions with unique community characteristics (e.g., high population of senior citizens, high density areas) may also want to consider selecting tools that are more adaptive to community traits.

- The accuracy of the tools can be increased by replacing national average input data with data generated at a local level. In some cases, updating the tools to include local data is relatively simple, but for other tools, the incorporation of local data would require reprogramming and recalibrating the tool.

In addition to evaluating tools to quantify GHG emissions, this report identified measures regional and local agencies can take to reduce mobile-source GHG emissions. Below are key findings of the evaluation of GHG emissions reduction strategies.

- Land use based strategies to reduce VMT have been shown to reduce mobile-source GHG emissions by up to 44 percent. These reductions are primarily due to changes in travel mode encouraged by placing compatible uses closer together and increasing the number of people who can access transit.

- Improving the operations of the transportation system can reduce mobile source GHG emissions by up to 20 percent. Operational improvement strategies include more efficient operations of traffic control devices (e.g., traffic signals, expanded use of roundabouts) and congestion management strategies (e.g., ramp meters, flexible work schedules).

- Effectively pricing the roadway system can reduce GHG emissions by up to 25 percent. These strategies encourage alternative modes of travel and travel during less congested times by charging a toll. The toll must be set strategically; however, to avoid increasing VMT by reducing overall congestion levels.

- There are other strategies available to reduce mobile-source GHG emissions, such as mandating more fuel efficient vehicles and promoting alternative fuels. While these strategies can be effective, they were not a focus of this report since they tend to require state or federal legislation.

- The short-listed GHG tools vary in their ability to evaluate the mobile-source GHG reduction strategies. The more sophisticated tools are better able to account for these strategies; however, combining the VMT output from some of the transportation-land use tools (VMT Spreadsheet with 4D Smart Growth Adjustments or TDF models) can increase the accuracy of the simpler tools.

RECOMMENDATIONS AND NEXT STEPS

Techniques for analyzing GHG emissions are rapidly evolving. As described earlier, this report represents a snapshot in time as of spring 2009 in terms of the tools available to evaluate GHG emissions, the approach by which practitioners are evaluating GHG emissions, and the strategies jurisdictions and agencies are adopting to reduce GHG emissions. Because this policy area is evolving so quickly, the project team recommends that Commerce regularly update this report to provide the latest information.

Listed below are some of the next steps that may be undertaken by Commerce, if funding becomes available, to assist regional and local agencies in addressing the challenges related to meeting the State's GHG reduction targets:

- Provide the report and web-based executive summary onto the agency's web site. The web site will provide links to each of the tools for jurisdictions to find additional information or software related to the tool.
- Seek funding to examine case study applications of the tools.
- Seek information from local agency partners on effective GHG emissions reduction strategies that have been successfully implemented.
- Develop a recommended approach to measuring and estimating land use-related GHG emissions from non-mobile sources.
- Encourage the development of a statewide mobile-source emissions factor and a set of emissions factors for each of the state's air basins.
- Identify tools that are useful at project-level review.
- Coordinate with the Washington State Department of Ecology regarding how these or other tools may be useful in environmental review under the State Environmental Policy Act (SEPA).
- Seek methods to incorporate non-mobile source GHG emissions, as well as improvements in fleet mix, fuel mix, and fuel economy into the tools available for GHG analyses.

Finally, Commerce should serve as a clearinghouse for information on the GHG tools. Given limited funding availability in the near term and no specific regulatory requirements, applications of the tools will occur on a voluntary basis. Commerce is actively seeking input from agencies that propose to use the tools in a planning application.

Since beginning this work in response to ESSB 6580 (2008) there have been continuing developments in state efforts to address climate change issues. For example, Governor Gregoire signed Executive Order 09-05, "Washington's Leadership on Climate Change" on May 21, 2009. In addition, the Legislature passed House Bill 1481 related to electric cars.

Other state actions include the passage of Senate Bill 5560, which contains language directing state agencies, beginning in 2010, to consider when distributing capital funds through competitive programs for infrastructure and economic development projects, whether the entity receiving the funds has adopted policies to reduce greenhouse gas emissions. The state agencies also must consider whether the project is consistent with: (1) The state's limits on the emissions of greenhouse gases established in RCW

70.235.020; (2) Statewide goals to reduce annual per capita vehicle miles traveled by 2050, in accordance with RCW 47.01.440, except that the agency shall consider whether project locations in rural counties, as defined in RCW 43.160.020, will maximize the reduction of vehicle miles traveled; and 3) Applicable federal emissions reduction requirements.

This report represents an analysis of the tools available in the late spring of 2009. As the tools advance, as technological advancements are made in the building and transportation industries, and as public policy continues to develop, future work may be needed to update the analysis of tools available.

GLOSSARY OF ACRONYMS

Acronym	Explanation
4Ds	4D variables (density, diversity, design and destination)
CACP	Clean Air and Climate Protection
CAPCOA	California Air Pollution Control Officers Association
CAT	Washington State Climate Action Team
CCAP	Center for Clean Air Policy
Commerce	Washington State Department of Commerce (formerly known as CTED, Community, Trade and Economic Development)
DRAM/EMPAL, UrbanSim, Uplan, ArcGIS, INDEX	Land use planning software
EMME, TransCAD, Visum, Synchro, Mobile 6	Transportation planning and analysis software
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse Gas Emissions
GREET	Greenhouse Gases, Regulated Emissions, and Energy use in Transportation
GRP	The Climate Registry's General Reporting Protocol
HOT	High-occupancy Toll Lane
ICLEI	International Council for Local Environmental Initiatives – Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
ITS	Intelligent Transportation Systems
LUCC	Land Use and Climate Change (Commerce advisory group)
MOVES	Motor Vehicle Emissions Simulator
NGGIP	National Greenhouse Gas Inventory Programme
NMIM	National Mobile Inventory Model
PLACE^{3}S	Planning for Community, Energy, Environmental, and Economic Sustainability
PSRC	Puget Sound Regional Council
RTPO	Regional Transportation Planning Organization
SEPA	Washington State Environmental Policy Act
TCR	The Climate Registry Local Government Operations Protocol
TDF	Travel Demand Forecasting
URBEMIS	California Air Resources Board's URBan EMISsions Model
VMT	Vehicle-Miles Traveled
WSDOT	Washington State Department of Transportation