Adding Green Performance Metrics to a Transportation Data Archive

Alexander Y. Bigazzi and Robert L. Bertini

Transportation sustainability is of increasing concern to professionals and the public. This paper describes the modeling and calculation of sustainability performance measures in a transportation data archive. The purpose of these measures is to assess the sustainability of the Portland, Oregon, metropolitan freeway system. The measures were developed to be part of, and to use the data from, the Portland Oregon Regional Transportation Archive Listing (PORTAL) at Portland State University. These performance measures estimate vehicle emissions (carbon monoxide, volatile organic compounds, nitrogen oxides, and carbon dioxide), fuel consumption, cost of time delay, and person mobility (travel in person hours and person miles and delay in person hours). Methods for modeling and necessary data are described. Future plans call for integrating these measures into the PORTAL web interface to expand the types of performance measures used for regional transportation planning and operations.

Policy makers and engineers are faced with growing concern over the sustainability of transportation systems. Internationally, road transport is the largest anthropogenic source of urban air pollution (1). Beyond emissions, transportation is a heavy user of society’s time and energy resources. Sustainability measures, also described as “green” measures, are needed to help guide decision makers by assessing the true operational impact of a transportation system.

The Portland Oregon Regional Transportation Archive Listing (PORTAL, see portal.its.pdx.edu) is a transportation data archive created to improve understanding of Portland’s transportation system performance. New metrics are needed that specifically address sustainability performance indicators. This paper describes initial steps in that direction: modeling and calculation of sustainability performance measures that can be incorporated into the PORTAL data archive for regional performance reporting, planning, and operations.

PORTAL DATA ARCHIVE

As shown in Figure 1, PORTAL has been gathering and archiving transportation data since 2004 that can later be retrieved and output over various time and space scales. Approximately 600 inductive loop detectors on Portland’s metropolitan freeways are the primary data sources for PORTAL. Data collected at 20-s intervals are streamed to the PORTAL servers, including count, occupancy, and time mean speeds in each lane. PORTAL also includes incident and variable message sign (VMS) data since 1999, 1 year’s worth of stop level bus data and hourly and daily weather conditions in Portland from automated weather stations. The four weather measures are temperature, visibility, wind speed, and rainfall.

From the basic sensor data PORTAL computes four other measures using road segment length: vehicle miles traveled (VMT), vehicle hours traveled (VHT), travel time, and delay. The road segment length is the distance between midpoints from adjacent detectors. Delay calculation uses an assumed free-flow speed of 60 mph. PORTAL includes a set of tools for plotting these measures for different locations and corridors over a range of temporal aggregations (2). For assessing variability and reliability, PORTAL includes plots of mean values plus or minus one standard deviation, as well as mean and 95th percentile values of specific measures such as travel time.

Other data sources are also being integrated into the PORTAL system, including freight weigh-in-motion data and statewide crash data. Efforts are made to minimize data errors and improve the quality of the measured data by identifying missing or erroneous data through error detection algorithms. Collected data fidelity is measured and reported in the system, enabling users to review the quality of the original data.

SUSTAINABILITY MEASURES

The concept of sustainability is becoming more important in transportation systems and is often broken into three component areas: environmental, economic, and social (3).

Environmental Sustainability

Transportation is a major contributor to urban air pollution through vehicle emissions (1). Road traffic generates air pollution in the forms of carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), hydrocarbons (HC), and others. Transportation also emits a significant amount of greenhouse gases, primarily carbon dioxide (CO2), which lead to anthropogenic climate change. Additionally, the massive energy demands of transportation systems deplete the natural resource base through consumption of nonrenewable fossil fuels.

Economic Sustainability

The cost of fuel consumed for transportation energy demands is enormous. Furthermore, the value of person time spent in the transportation system must be considered. Delay due to transportation...
system congestion is an inefficient use of society's time resource. Other economic tolls of the transportation system include crashes (material and human costs) and infrastructure development and maintenance costs.

Social Sustainability

Social sustainability addresses the just distribution of benefits in a society. Primary concerns of social sustainability in transportation are access and mobility. Access to transportation of various modes should be considered. Time lost to congestion delay has an economic impact on society, as mentioned above, as well as a social impact as congestion decreases time available for social interactions.

Selected Measures

The PORTAL project has selected several important “green” measures that can be effectively incorporated into the data archive itself. Touching on all three areas of sustainability, the metrics explored in this paper are as follows:

- Emissions—air pollution and greenhouse gases due to exhaust and evaporative emissions, in pounds of CO, HC, NOx, and CO2;
- Energy consumption—fuel usage in gallons of fuel (can also be converted to dollars);
- Delay cost—time value of delay to transportation system users in dollars; and
- Person mobility—person miles traveled (PMT), person hours traveled (PHT), and person hours of delay (PHD).

EMISSIONS

Factors Affecting Emissions

The main influences on vehicle emissions can be divided into six categories: travel, weather, vehicle, roadway, traffic, and driver-related factors (4). Most emission models capture travel, weather, and vehicle influences well, but do not sufficiently address roadway, driver, and traffic factors. Transportation operation improvement projects often affect these last three influences, and, as a result, emissions effects can be difficult to predict or measure (5).

Travel

Vehicle travel, usually measured in VMT, is the primary determinant of vehicle emissions. Travel quantities are included in almost all emissions estimates, except for wide-scale carbon emission based on regional fuel sales. VMT and other travel measures are sometimes used as surrogate metrics for emission comparisons between regions.

Traffic

Traffic flow and operation is an important factor in urban emissions. Congestion levels affect vehicle speeds and vehicle modes of operation. Kühlwein emphasizes the importance of monitoring congestion for high-quality emissions modeling on road sections (6). Speed variability during congestion increases emissions through increased accelerations. High-speed accelerations such as experienced in dense, high-speed traffic cause especially heavy emissions.

Uncongested freeway conditions can also lead to high emission rates because of high speeds. Mild accelerations at high speeds can
lead to higher emissions on uncongested freeways than on slower, moderately congested freeways. Vehicle emissions are typically lowest at medium speeds (30 to 50 mph) (7). Medium speeds avoid the heavy emissions that result from fuel enrichment (incomplete combustion) during high-intensity engine operation, while staying above the inefficiencies of low-speed vehicle operation. Traffic congestion is an important consideration in emissions because it affects not only average speed but speed variation as well.

Driver Behavior

Modifying individual driving behaviors can affect emissions by 5% to 25% (8). Different driving styles can result in vehicle operation in substantially different modes over the course of a trip, and vehicle mode of operation is a major factor in emissions. Fluidity and steadiness of speed yield the least emissions, whereas aggressive accelerations and high speeds generate the most. The CO produced by one heavy acceleration can exceed that produced by the remainder of a short trip (9), and excessive highway speeding can double the vehicle emission rate of CO (8).

Roadway

The design and condition of a roadway affect emissions in many ways. Steep highway grades cause increased emissions, especially at high speeds. Surface roughness can increase emissions by increasing rolling resistance. Design aspects such as curvature and superelevation also affect vehicle accelerations and operating mode.

Weather

Weather affects mostly evaporative (nonexhaust) emissions. Temperature and humidity influence the evaporative emission rate during engine operation and rest, as well as evaporative losses during refueling. Exhaust emissions are affected by cold weather because of decreased engine efficiency (especially during the warm-up period) and decreased effectiveness of catalytic converters in capturing emissions. Temperature and sun intensity also affect vehicle air conditioning usage, which increases engine loads.

Vehicle

The factors above determine vehicle mode of operation through engine loads. The size, age, condition, weight, shape, type, and technology of a vehicle determine how those factors are translated into emission rates. High engine loads generate the highest emission rates for individual vehicles, but those rates vary among vehicles. The importance of nonexhaust (evaporative) emissions decreases as speeds increase (10). Vehicle fleet distribution and usage over facility, vehicle class, and age are important considerations for detailed emissions estimates.

Emission Modeling

It is convenient to separate travel-based emission models into two main types: average speed models and modal models. Average speed models use average speeds as their principal input and generally deal with regional or citywide estimates. Modal models base emissions on the operating mode of individual vehicles and can perform estimates on roadway links. Modal link estimates can be aggregated into larger spatial areas, but the process requires significant data and computational resources.

In general, significant error and uncertainty exist in application of most emission models (11). Emission models are often used in conjunction with legislative compliance. As a result, models and related studies often address only the accuracy and resolution required to comply with regulations (9). Where local data are not available for model inputs, regional or national averages can be assumed to apply. However, actual measurements markedly improve emissions estimates on a local level over regional traffic data (6).

CO₂ is sometimes estimated separately from other emissions. Because CO₂ is the dominant carbon end result of fuel combustion, conversion is commonly made between CO₂ and fuel consumption by assuming complete oxidation of the carbon content (96%) of fuel (12). Fuel consumption can be determined from regional sales data or from road speed fuel models (13). Similarly, sulfur dioxide can be estimated from fuel consumption by assuming complete oxidation of the fuel sulfur content.

Average Speed Models

Average speed emission models are regularly used in practice. Their main advantages are simplicity and limited data needs (sometimes only average speed and VMT). These are typically large-scale models suited for city, state, and national estimates (14). Average speed models capture travel, vehicle, and some traffic effects, but most driver and roadway influences are neglected. Weather can be an input parameter for some average speed models.

The creation process for most average speed models involves four steps. Initially, probe vehicles record drive cycles (speed over time for a full trip) in a representative sample of driving conditions. These drive cycles are key to the accuracy and relevance of average speed models (15). The second step involves testing of vehicles on a dynamometer. Sample vehicles from different classes of the vehicle fleet are tested for actual emissions over the drive cycles from one step. The third step relates emission rates to average speeds based on the drive cycles tested. Finally, by knowing average road speeds and vehicle fleets, area emissions can be estimated by combining emission rates with vehicle travel. This process can be refined by adding inputs such as weather and facility-specific drive cycles and VMT.

Estimates based on average speed can be improved by including an average speed distribution, more accurately representing the road traffic conditions. Adding average speed distribution to simple average speed can increase total network emissions by up to 9%, with even larger increases at road section levels (16). Because of the data collection method, PORTAL speed data are averaged over 20-s intervals. While instantaneous speed distributions are not measured, speed distributions can be estimated from 20-s average lane speeds.

Using average speed distributions does not account for driving dynamics (speed fluctuations). This is especially important on a local scale, where driving conditions may vary significantly from standard drive cycles. If the scope of an emissions estimate is sufficiently large, speed dynamics can reasonably be neglected (16). For small-scale urban estimates, congestion drive cycles can effectively model realistic speed variations during congestion. These congested drive cycles can generate emissions up to four times heavier than free-flow
drive speeds (17). Even using congestion drive cycles, most average speed models cannot fully capture the effects of traffic operation improvements such as traffic signal coordination and ramp metering. Examples of average speed emission models in use around the world include the International Vehicle Emissions model, COPERT, CORINAIR, TRAEMS, EMFAC (from the California Air Resources Board), and MOBILE (from EPA). MOBILE is the standard for North American emissions modeling and is discussed below. The latest version, MOBILE 6, includes many updates such as new facility-specific congestion drive cycles collected in U.S. cities, updated vehicle and fuel technologies, and user-input hourly speed distributions.

Modal Models

Modal models use a combination of roadway, driver, and traffic factors to determine the vehicle driving mode of operation (idle, cruise, acceleration, deceleration). The operation mode is then combined with vehicle and weather factors to determine emission rates based on vehicle test data. Vehicle test data can relate to emissions through a speed–acceleration matrix, a map of engine power and speed, or a physical parameters model (9).

The accuracy of modal models resides in the importance of speed and acceleration on vehicle emission rates. Modal models are useful for predicting emissions effects of operational improvements, as well as improving accuracy of regional estimates. Data requirements can be heavy, because detailed velocity patterns are required for each vehicle. Applied over large networks, the computational and data requirements can quickly become “unruly” (7).

MOBILE 6 Model

MOBILE 6 was selected as the emissions model for this project. A modal model would require more data than are available in PORTAL (specifically, vehicle acceleration rates). The MOBILE 6 model provides a higher degree of precision than other average speed models and was developed with vehicle traits and usage patterns specific to modern U.S. cities. Although congestion levels are not specifically input in MOBILE 6, facility-specific drive cycles implicitly account for congestion by linking level of service to average speeds by facility type (17).

Applying MOBILE emission factors to individual road sections is a misapplication because the factors were derived from complete vehicle trips (16, 18). However, by neglecting vehicle starts and distributing all VMT to the freeway facility, MOBILE 6 can provide reasonable estimates of freeway section emissions. Another concern is the speed limitation of MOBILE 6 modeling. High freeway speeds generate heavy emissions because of the engine loads, but MOBILE 6 cannot distinguish speeds above 65 mph because of limited vehicle test data. If a significant portion of vehicles are traveling above 70 mph, the emission factors may underestimate the true emission rate (7).

The emissions estimate methodology began with a PORTAL query for relevant speed and travel data. A MOBILE 6 input file was created and then the model was run. The model generated emission factors in weight per vehicle mile for each hour and station of interest. Measured data or local averages were used whenever possible for input values. For values that could not be ascertained, either state averages or MOBILE 6 default values were used (based on national averages). A next step in increasing the accuracy of these estimates is to obtain more local data to replace state or national averages. A description of various input parameters follows.

Vehicle Mix and Mileage

MOBILE 6 uses 28 vehicle classes to describe the vehicle fleet. Some local data were available, but vehicle class definitions did not always agree. For example, MOBILE 6 classifies heavy-duty vehicles (HDVs) by weight, while the Federal Highway Administration HDV classes are by axles and wheels. Default MOBILE 6 values (national averages) were used for vehicle registrations, mileage accumulation rates, natural gas vehicles, and diesel fractions (diesel sales percentage for each vehicle class).

PORTAL calculates an estimated auto/truck split, which was used to customize average freeway vehicle fleets. Two important VMT measures were specified from PORTAL data: VMT by hour and VMT by speed. VMT by hour describes the fraction of daily VMT that occurs during each hour of the day. VMT by speed describes the hourly speed distribution of VMT in 5 mph bins, up to 65 mph. VMT by facility was custom input as 100% freeway because all PORTAL data were collected on metropolitan freeways. Emissions measures are highly sensitive to the overall vehicle fleet (especially auto/truck splits and speed distributions), but have low sensitivity to certain individual components (natural gas vehicles, diesel fractions).

Weather

Weather input includes temperature, humidity, cloud cover, and sunrise and sunset. PORTAL weather data were used to provide daily minimum and maximum temperatures. Although hourly temperature input is also an option for MOBILE 6, emissions factors were found not to be sensitive to the style of temperature input. Other weather input utilized long-term monthly averages for the Portland area. For these analyses, it was found that customizing weather parameters had small to moderate effects on emissions rates.

Emissions Programs

Oregon Department of Environmental Quality requires inspection of Portland area vehicles every 2 years. MOBILE 6 input was customized for available details of Portland’s inspection and maintenance program (type of inspections, model years required, pass/fail rate), and default data were used for other aspects of the program (program waivers, effectiveness). Default values for fuel programs used federal EPA guidelines and national averages regarding fuel content and sales (sulfur content, liquid natural gas sales, etc.). The fuel Reid vapor pressure (RVP) is a required parameter relating to the volatility of fuel. Monthly average values were obtained from EPA data for Multnomah County, Oregon (19). Except for RVP, emissions measure sensitivity was low with respect to parameter customization for these vehicle inspection and fuel programs.

Other Parameters

Other inputs for running the MOBILE 6 model included the calendar year, season, and altitude. The program was directed to run with no vehicle starts and no refueling losses (because only modeling freeways). The pollutants selected were CO, HC (expressed as volatile organic compounds, VOC), NOx, and CO2. MOBILE 6 output can be specified in the form of summary text, spreadsheet, or detailed database. Although the size is much larger, the database output is required to produce hourly emission rates for estimating emissions over the course of a day.

Emission Measures

A sample day was chosen for analysis (Friday, July 1, 2005) that had high data quality for the detector station of interest (I-5 northbound...
at Broadway, milepost 302.5). For total emissions on this freeway section, the modeled emission factors were multiplied by measured station VMT. A road section is considered to be the distance between the midpoints from adjacent detector stations. Emission density was calculated as emission factors multiplied by the station volume. Figure 2 is presented as an example of PORTAL’s ability to model hourly emissions. The charts show VOC emission density at the station and CO₂ total emissions on the road segment. In order to examine the effects of congestion on emissions, this same station and day were modeled assuming free-flow speed. For free-flow analysis, all VMT was attributed to one speed bin. Figure 3a shows hourly emissions of CO over the course of the day for free-flow conditions (all vehicle travel assumed to be at 60 mph) and actual speeds. As discussed above, emissions are typically lowest at medium speeds. Actual average speeds slightly below 60 mph through most of the day produced lower CO emissions, except for the 3 p.m. to 5 p.m. time period when very slow congested speeds increased emissions. The 60 mph free-flow speed was selected because PORTAL uses that speed for delay calculations.

Another method of viewing congestion effects is presented in Figure 3b. The percentage increase of hourly VOC emissions for actual average speeds as compared to 60 mph free-flow speeds is

![Bar chart showing hourly VOC emissions for free-flow conditions and actual speeds.](image)

![Bar chart showing hourly CO₂ emissions for free-flow conditions and actual speeds.](image)

**FIGURE 2** VOC and CO₂ emissions model outputs: (a) hourly VOC density on July 1, 2005, and (b) hourly CO₂ emissions on July 1, 2005.
shown for the same day and location as above. Heavy afternoon congestion causes VOC emissions to triple for the 4 p.m. hour. Emission rates for different pollutants change with traffic speeds in different ways. Although air pollution emissions vary significantly with speed, CO₂ emissions do not. It should be noted that MOBILE 6 does not model speed-dependent CO₂ emissions, but instead uses a carbon balance with average fuel consumptions based on other input parameters. This is a limitation that is expected to improve with the EPA’s forthcoming MOVES emissions model.

Portland area air quality data were compared with daily emission estimates over the course of 1 month. Daily carbon monoxide levels as recorded by an air monitoring station were obtained for January 2005. Estimated daily emissions of CO along I-5 in Portland were computed for the same month. Figure 4 shows the result of plotting each of these values as a percentage of the monthly average. Some correlation is evident, although it is an overly simple analysis. Many other sources of CO in Portland exist (other road emissions and nonmobile sources) and atmospheric conditions on CO are not considered. As an example, the highest mean daily temperatures for the month were recorded from January 18 to 23, 2005, corresponding with the period of high measured CO.

FUEL CONSUMPTION

Methods of Estimation

For regional estimates, fuel consumption is often assumed to be equal to regional fuel sales if no significant price differences exist with bordering areas. This method is not easily applied at
local levels because relevant fuel sales data are not often available. Furthermore, this method has a coarse time resolution because of the infrequency of refueling.

Just as CO₂ emissions are often estimated from a carbon balance with fuel sales data, fuel consumption can be estimated by a carbon balance with modeled CO₂ emissions. The accuracy of this method depends on the accuracy of the CO₂ estimate. Average speed models work well for this purpose because fuel consumption and CO₂ emissions are not as sensitive to speed as air pollutant emissions. Furthermore, fuel consumption is not affected by enrichment during heavy engine loads in the way that air pollutants are affected (7). Models that calculate fuel consumption directly from average speed rely heavily on the relevance of sampled vehicle testing for their accuracy. A simple method for fuel consumption estimation is to calculate an average vehicle fleet fuel economy based on vehicle data and vehicle class distribution. This aggregate fuel economy can then be used with travel data to calculate fuel consumption.

MOBILE 6 was selected to model fuel consumption from PORTAL data. As compared to a fuel sales-based estimate, the MOBILE 6 model allows for calculation of fuel consumption on individual road sections. MOBILE 6 models fuel economy based on fleet data such as diesel fraction, vehicle age, mileage accumulation, VMT distribution, and fuel programs. The vehicle fleet fuel consumption rate (in gallons per mile) is simply the inverse of fleet fuel economy (in miles per gallon).

Overall fleet fuel economy was not sensitive to most input variables for the emissions model. The fleet and fuel factors that most influenced fuel economy were long-term averages and held constant for half-year periods. For this reason, MOBILE 6 fuel consumption rate estimates were generated and recorded for 6-month periods back to 2002 (the beginning of PORTAL travel data). In this way fuel consumption estimates can be calculated from recorded fleet consumption rates rather than running individual models.

Fuel Measures

Historical fleet fuel economies generated by MOBILE 6 for the past 6 years range from 16.6 to 17.0 miles per gallon. Fuel consumption rate (the inverse of fuel economy) can be multiplied by VMT or volume data to calculate fuel consumption or fuel consumption density (per freeway mile). This method does not measure congestion effects on fuel consumption because fuel economy is not sensitive to average speed in MOBILE 6. As two examples of fuel consumption estimates using PORTAL, Figure 5a shows hourly fuel consumption density for 1 day and Figure 5b shows total daily fuel consumption for 1 month at the detector station on I-5 north at Broadway.

DELAY COST

Estimating the Value of Time

To calculate the value of the time lost to congestion delay, an estimate must be made of time value for freeway vehicles. The time values selected are based on Oregon Department of Transportation (ODOT) estimates from current wage rates, benefits rates, vehicle occupancies, and work trip percentages. ODOT released time value estimates for the years 2003, 2005, and 2007 (20). Averaging and adjusting for inflation based on the consumer price index generates values for the remaining years (back to 2002).

The ODOT time value estimates are for three vehicle categories: autos, light trucks, and heavy trucks. Because PORTAL loop detector vehicle class estimates are in just two categories (auto and truck), the two truck categories were combined. The fractions of light and heavy trucks (0.578 and 0.472, respectively) were taken from national averages, as represented by the MOBILE 6 default VMT mix. The annual values of time per vehicle hour, using current-year dollars, range from $15.10 in 2002 to $18.04 in 2008 for automobiles and $24.35 in 2002 to $26.53 in 2008 for trucks. This method could be improved with better local estimates of work trip percentages by hour and roadway.

Delay Cost Measures

Delay cost as calculated here assesses the value of lost time only, not congestion costs related to vehicle usage, crashes, or fuel. Use
of the annual time values for autos and trucks with the auto/truck split calculated in PORTAL produces hourly values of time per vehicle hour. These hourly roadway time values increase with the percentage of trucks present. The time values are then multiplied by PORTAL hourly delay to determine the cost of delay. As an example, Figure 6a shows the cost of delay over the course of a day for one loop detector station, illustrating the cost of afternoon congestion. Figure 6b presents the daily cost of delay for the same station over the month of July in 2005. The effect of varying daily congestion can be seen. Using PORTAL, delay costs can be aggregated over various combinations of space and time.

PERSON MOBILITY

Vehicle Occupancy

Person-level mobility and delay can be extracted from vehicle data using assumed vehicle occupancies. The ODOT value of time estimates described above include average vehicle occupancies for autos, light trucks, and heavy trucks. As with the time value calculations, the two truck values were combined by using an average truck fleet to produce a composite truck occupancy of 1.07 persons per vehicle. The auto occupancy was 1.55. In actuality, auto occupancies will likely...
vary with time of day, day of week, and season because of commute and recreational trip differences. For this reason, person-level mobility measures, such as delay cost measures, would benefit from improved local estimates regarding work trip percentages.

Similar to the ODOT time value estimates, these two vehicle class occupancies are considered static over time (back to 2002). The auto and truck vehicle occupancies were combined with PORTAL auto/truck split estimates to produce hourly average roadway vehicle occupancies for calculation of person measures.

**Person Measures**

Hourly roadway vehicle occupancy can be multiplied with the VMT, VHT, or delay output from PORTAL to produce PMT, PHT, or PHD. PHD measures the effects of congestion on individual person time. Two examples are provided for the loop detector station on I-5 North at Broadway. Figure 7a shows hourly PHT over the course of 1 day, and Figure 7b shows average PHD by day of week for the month of July, 2005. Person mobility and delay measures can be aggregated over various sections of roadway or various lengths of time.

**CONCLUSION**

The “green” performance measures described in this report for emissions, fuel consumption, delay cost, and person mobility will add a new dimension to the PORTAL data archive. They offer key transportation system sustainability indicators that can readily be calculated from existing PORTAL data.

While these measures can offer new insights, their limitations must also be understood. They rely on the accuracy of the input data as well as the models. A more detailed estimate could be made of any one measure for a specific time and location, but these are
designed to apply over the entirety of the PORTAL data network and to facilitate comparisons over time. Future work should focus on increasing the accuracy of these estimates by obtaining more Portland-specific data and refining the model inputs.

Incorporating new performance measures into the transportation planning process can be a challenge. PORTAL was established with the conviction that a better understanding of how the system performs can lead to better decision making. New approaches to integrating sustainability performance measures with transportation planning are being developed (21). The state of the practice of sustainability performance measures varies greatly by region. Metropolitan Atlanta, Georgia, is one example of an urban area that has been working to establish sustainability indices for both performance measurement and planning goals (22).

Although decision makers can access PORTAL performance measures directly, a more likely channel is that PORTAL data will be used by transportation professionals and researchers to support transportation policy initiatives. Sustainability performance measures can be used to attach estimates of green effects to research efforts.

The next step in this project will be online, automated implementation of these measures based on the methods described here. This will allow rapid calculation of sustainability metrics over any time and space scale available in PORTAL. Results will be available in graphical and tabular format, as well as in a geographic information systems representation. Other sustainability measures for future consideration include noise pollution, transit VMT share, infrastructure cost from freight travel, and cost of vehicle crashes.

ACKNOWLEDGMENTS

Funding and support for this project were provided by the National Science Foundation, Oregon Department of Transportation, FHA, City of Portland, TriMet, and Metro. The authors thank the PORTAL development team, PORTAL users, and the TransPort ITS committee for their feedback and support.
REFERENCES


The Urban Transportation Data and Information Systems Committee sponsored publication of this paper.