GUIDE TO SUSTAINABLE TRANSPORTATION PERFORMANCE MEASURES

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All cover photos are courtesy of EPA. From top: Salt Lake City, Utah; Starkville, Mississippi; Boise, Idaho.

Table of Contents

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Executive Summary

This document describes opportunities to incorporate environmental, economic, and social sustainability into transportation decision-making through the use of performance measures. Performance measures allow decision-makers to quickly observe the effects of a proposed transportation plan or project or to monitor trends in transportation system performance over time.

While many transportation agencies use performance measures as part of planning and project development, their use to promote sustainability has historically been limited. However, more and more agencies have begun to measure the ability of their systems to help protect natural resources, improve public health, strengthen energy security, expand the economy, and provide mobility to disadvantaged people. This document provides examples of best practices in sustainable transportation performance measurement that are being applied across the country.

The measurement of environmental, economic, and social outcomes is already yielding positive results. Many agencies have found that, once they begin to report sustainable transportation performance measures, stakeholders quickly see their value and come to expect regular reporting of measures and more explicit linkages between the measures and public agency decisions. Agency staff and stakeholders are then able to engage in a much richer conversation about the trade-offs among policy and investment decisions and the best opportunities for their region or state to reach its sustainability goals.

Sustainable performance measures can be applied in one or more of these major decision-making phases:

- Land use visioning.
- Long-range transportation plans.
- Corridor studies.
- Programming.
- Environmental review.
- Performance monitoring.

This guidebook describes 12 performance measures that can readily be applied in transportation decision-making. The document focuses on transportation decision-making at the regional or metropolitan level, although many of the performance measures described could be used at the state or local level. For each measure, the guidebook presents possible metrics, summarizes the relevant analytical methods and data sources, and illustrates the use of each measure by one or more transportation agencies. The 12 profiled measures are:

- Transit accessibility.
- Bicycle and pedestrian mode share.
- Vehicle miles traveled per capita.
- Carbon intensity.
- Mixed land uses.

- Transportation affordability.
- Distribution of benefits by income group.
- Land consumption.
- Bicycle and pedestrian activity and safety.
- Bicycle and pedestrian level of service.
- Average vehicle occupancy.
- Transit productivity.

The guidebook then describes opportunities to apply sustainable performance measures in the transportation decision-making process. It provides examples of how metropolitan planning organizations have used sustainable performance measures as part of the following activities:

- Long-range plan: identifying vision, goals, and targets.
- Long-range plan: project performance assessment.
- Long-range plan evaluation.
- Corridor level evaluation.
- Programming.
- Performance monitoring.

The examples described are indicative of the growing interest in performance-based planning and in making transportation environmentally and economically sustainable over the long term. Drawing on the transportation agency experiences described here, this guidebook can spur further interest and innovation in these fields.

1. Sustainability in Transportation Decision-Making

Many transportation agencies are now being called upon by their stakeholders to plan, build, and operate transportation systems that – in addition to achieving the important goals of mobility and safety – support a variety of environmental, economic, and social objectives. These include protecting natural resources, improving public health, strengthening energy security, expanding the economy, and providing mobility to disadvantaged people.

This shift has been decades in the making and is driven by a variety of factors. One factor is the desire for a more integrated and holistic approach to transportation decision-making. Researchers have been shedding light on the complex interrelationships between our built and natural environments and drawing attention to the need to better consider the multifaceted implications of transportation system changes. At the same time, advanced computer tools are making it easier to quantify and visualize these relationships.

Other important societal priorities are also driving the need to consider these goals in transportation decisions:

- *Environmental Quality.* While pollutant emissions from motor vehicles have dropped dramatically over the last three decades, air quality problems persist in many metropolitan areas, driven in part by growth in vehicle miles traveled (VMT). Recent scientific research has more clearly linked air pollution with public health problems and led the U.S. Environmental Protection Agency (EPA) to establish lower thresholds for acceptable levels of air pollution. On a global scale, the looming threat of climate change has focused attention on the environmental impacts of the transportation sector, which contributes more than 25 percent of our nation's greenhouse gas (GHG) emissions.
- *Economic Development.* Transportation has long been recognized as essential to economic development. Efficient and reliable movement of people and goods improves productivity and can spur economic growth. Moreover, with rising regional competition, quality of life has become increasingly important for drawing and retaining a talented and productive workforce. Transportation investments are key to boosting a region's attractiveness to businesses and residents.
- *Social Equity.* People who are economically, socially, or physically disadvantaged need transportation options to give them opportunities to work, learn, and participate in society. Transportation is a large and growing expense for many families. Households in locations with poor accessibility to employment opportunities and other destinations and no alternatives to driving tend to spend more on transportation. Investments that improve accessibility and provide more transportation choices allow households to save money.

There no single definition of what constitutes a "sustainable" transportation system. According to the definition endorsed by the Transportation Research Board Sustainable Transportation Indicators Subcommittee, a sustainable transport system:[1]

- "Allows the basic access and development needs of individuals, companies, and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.

- Is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.
- Limits air, water, and noise emissions, waste, and resource use. Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise."

The interagency Partnership for Sustainable Communities reinforces the importance of environmental, economic, and social sustainability. On June 16, 2009, the U.S. Department of Housing and Urban Development (HUD), the U.S. Department of Transportation (DOT), and EPA agreed to coordinate housing, transportation, and environmental policies and investments. The Partnership breaks down long-standing silos to increase transportation options, improve accessibility to jobs and other destinations, and lower the combined cost of housing and transportation while protecting the environment in communities nationwide. The Partnership is guided by six livability principles:[2]

- *Provide more transportation choices.* Develop safe, reliable, and economical transportation choices to decrease household transportation costs, reduce our nation's dependence on foreign oil, improve air quality, reduce greenhouse gas emissions, and promote public health.
- *Promote equitable, affordable housing.* Expand location- and energy-efficient housing choices for people of all ages, incomes, races, and ethnicities to increase mobility and lower the combined cost of housing and transportation.
- *Enhance economic competitiveness.* Improve economic competitiveness through reliable and timely access to employment centers, educational opportunities, services and other basic needs by workers, as well as expanded business access to markets.
- *Support existing communities.* Target federal funding toward existing communities—through strategies like transit oriented, mixed-use development, and land recycling—to increase community revitalization and the efficiency of public works investments and safeguard rural landscapes.
- *Coordinate and leverage federal policies and investment.* Align federal policies and funding to remove barriers to collaboration, leverage funding, and increase the accountability and effectiveness of all levels of government to plan for future growth, including making smart energy choices such as locally generated renewable energy.
- *Value communities and neighborhoods.* Enhance the unique characteristics of all communities by investing in healthy, safe, and walkable neighborhoods—rural, urban, or suburban.

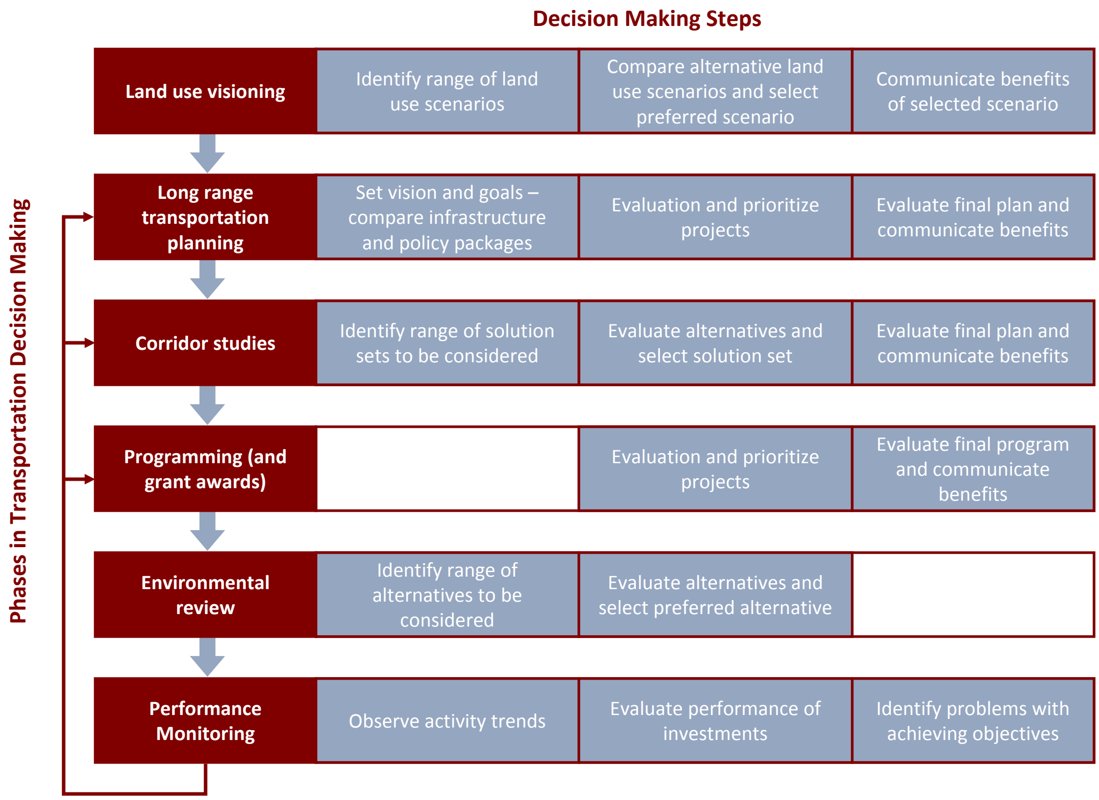
HUD, DOT, and EPA will use performance measures to target their resources towards planning and capital programs that support the livability principles, to create baselines for measuring progress toward sustainable communities objectives, and to evaluate federal initiatives. These livability-focused performance measures will complement traditional transportation metrics and will have varied applications for rural and metropolitan regions. The measures described in this document can help transportation agencies work toward the livability goals of their regions.

2. Performance Measurement in Transportation Decision-Making

Transportation agencies can better integrate the concepts of sustainability into their planning, programming, and project development activities through performance measures. Performance measures provide quantified evidence of the consequences of a decision or action. By translating data and statistics into a succinct and consistent format, performance measures offer an efficient way to provide information to decision-makers.

Transportation performance measures predict, evaluate, and monitor the degree to which the transportation system accomplishes adopted public objectives. They can be applied at all stages of transportation decision-making, as illustrated in Figure 1.

Figure 1: Opportunities to Use Performance Measures to Improve Transportation Sustainability
Image source: ICF International



Land Use Visioning

Some metropolitan areas have conducted land use visioning exercises, sometimes called scenario planning, in an effort to reach consensus on a desired regional growth pattern. In these exercises, regional stakeholders work to develop a shared vision for the future by analyzing various forces (e.g., health, transportation, economic, environmental, land use) that affect growth. A land use visioning process usually includes hands-on stakeholder involvement in developing and selecting a range of options for future growth.

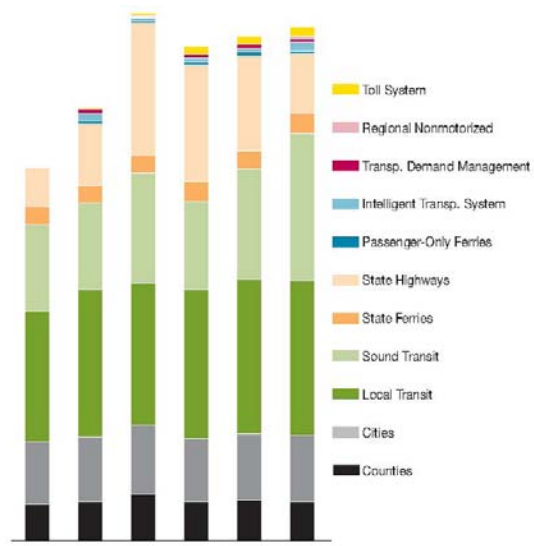
While not directly part of the long-range transportation planning process, land use visioning can result in an adopted growth forecast that informs subsequent transportation investment decisions. It can also produce preliminary guidance on transportation improvement programs. Performance measures are frequently used to evaluate and compare alternative land use scenarios and then to communicate to the public the benefits of an adopted growth vision.

Long-Range Transportation Planning

Long-range transportation planning provides the foundation for all other aspects of transportation decision-making by establishing the vision and goals for transportation and identifying strategies and project concepts for implementation. The outcome of long-range transportation planning should be broad-based consensus and support for the transportation strategies and project concepts that are recommended. Collaboration with partners and stakeholders is essential if these decisions are to be recognized and built upon during subsequent corridor planning and project development.

Performance measures can be used in several ways during transportation planning. Once a community has established goals and objectives for the transportation system, performance measures can be used to explore how different policy and investment packages can help achieve the objectives. At this visioning stage of the long-range transportation planning process, individual projects are not well defined, and planners create deliberately distinct policy and investment packages to illustrate the effects of various bundles of policies. Figure 2 illustrates five alternatives considered in the development of the Puget Sound Regional Council's (PSRC's) Transportation 2040 Plan.[3]

Figure 2: Puget Sound Regional Council – Alternatives Considered in Development of Transportation 2040 Plan



Performance measures can also be used to evaluate individual projects and programs being considered for inclusion in the plan. Project-level assessment is time consuming, and rarely are agencies able to quantitatively evaluate all projects submitted for consideration individually. As a result, it is most important to apply performance measurement to the most expensive projects.

Once a region has reached consensus on project priorities and adopted a long-range plan, performance measures can be used to compare the plan against current conditions or a future business-as-usual scenario. The results can help communicate the benefits of the plan to the public.

Corridor Studies

Corridor planning builds on the foundation of long-range planning by studying concepts and solutions for individual corridors or small areas within a region, leading to the selection of a preferred concept. Corridor planning is not a legally required process, so the purpose and process of corridor planning efforts can vary considerably. In some metropolitan areas, corridor plans are done concurrently with the development of the long-range plan. In rural areas, corridor plans are sometimes used as a substitute for long-range plans.

Performance measures can help transportation agencies identify alternatives to be considered during corridor planning and facilitate comparison across alternatives and selection of a preferred option. The performance measures used in corridor studies have traditionally focused on congestion reduction and vehicle mobility. But planners are finding that use of measures to evaluate environmental, economic, and social equity outcomes can help identify a more widely accepted alternative and avoid unnecessary delay during the subsequent environmental review process.

Programming

Programming is the process by which agencies select and invest limited transportation funds in a list of projects that will be built within a set time frame, usually three to five years. The transportation improvement program (TIP) is a list of prioritized projects, drawn from the long-range transportation plan, that are approved for funding. The use of performance measures at this stage often involves a benefit-cost metric that encompasses multiple categories of benefits.

In addition to the formal TIP process, performance measures are ideal for selecting among smaller transportation projects to receive state or regional grant support. For example, several metropolitan planning organizations (MPOs) have established programs to fund local government bicycle and pedestrian improvements and other transportation investments that support compact and transit-oriented development. Requests for funding from these programs often exceed total available funds. Performance measures can be used to screen grant applications and select projects for funding that are most supportive of regional sustainability objectives.

Environmental Review

Environmental review is a regulatory process that encompasses the actions required under the National Environmental Policy Act, the Clean Water Act, the Endangered Species Act, and various other state and federal regulations. Environmental review is generally the last step in the planning process for a transportation improvement and is followed by final design and construction. By the time of environmental review, the location and general parameters of a project have been decided. Performance measures can be instrumental in selecting a project alternative and associated mitigation measures that minimize adverse impacts.

Performance Monitoring

Many metropolitan areas create annual "state of the region" reports that track progress using a set of key performance measures. Performance monitoring allows a region to view trends in a variety of quality of life indicators in areas such as employment, poverty, housing, congestion, air quality, energy, waste, education, and public safety. Performance reports can also allow a region to compare itself against peer regions.

MPOs often report indicators that relate to regional planning goals. The Delaware Valley Regional Planning Commission, for example, reports 27 indicators organized under five categories:

- Growth management.
- Urban revitalization.
- The environment.
- Economic development.
- Transportation.

Figure 3 shows an example of how the Delaware Valley Regional Planning Commission has presented results of its performance monitoring program.[4]

Typically, regional performance monitoring involves reporting indicators that are already compiled and analyzed for other purposes. In some cases, MPOs have launched new initiatives to develop a much larger set of performance measures. The Chicago Metropolitan Agency for Planning, for example, has a Regional Indicators project that involves creating more than 500 tables to measure more than 200 indicators across different times and regional geographies.

Performance monitoring can inform transportation investment decisions by highlighting trends that may be inconsistent with regional objectives. The use of performance measures for monitoring can also help to illustrate the impacts of specific transportation investments and programs.

Figure 3: Delaware Valley Regional Planning Commission – Performance Monitoring Results

What We Track		How is the DVRPC Region Performing?	Trend
TR 1:	Have vehicle crashes and fatalities declined?	Between 2001 and 2005, the DVRPC region experienced an 18% decrease in fatalities per million VMT and less than 1% decrease in all crashes per million VMT. However, the overall number of crashes rose by 4.6% during this same time period.	
TR 2:	Is congestion getting worse?	Congestion appears to be stable – neither improving nor worsening, though VMT has increased.	
TR 3:	Is transit ridership increasing?	While transit ridership has experienced some fluctuation, it has increased in the last 5 years.	
TR 4:	Has the number of deficient bridges in need of rehabilitation or replacement decreased?	The number of bridges identified as structurally deficient in the DVRPC region has remained steady, but remains twice as high as the acceptable level set by FHWA in its current strategic plan.	
TR 5:	Are roads better maintained?	The region saw a slight increase in road miles considered to be deficient, mostly due to NJDOT's stricter standards.	
TR 6:	Are fewer people driving to work alone?	The number of people driving to work by themselves continues to increase and is now 73% of all commuters.	
TR 7:	Are people driving less?	There are more cars and more drivers driving more miles every year in the region. The region appears to be more auto-dependent.	
TR 8:	Are DVRPC's TIP investments in keeping with the LRP goals?	Approximately 97% of the mapped 2007-2010 TIP project funding supports the Long Range Plan and its stated goals.	

3. Performance Measure Examples

This section describes 12 performance measures that can help to incorporate sustainable communities objectives into transportation decision-making. These examples are not intended to be a comprehensive set of measures, nor are they necessarily the 12 most appropriate measures for a given community. They were selected as representative examples that span the various phases of transportation decision-making and the different elements of sustainability. All the measures profiled have been used by one or more transportation agencies. The performance measures are:

- Transit Accessibility.
- Bicycle and Pedestrian Mode Share.
- VMT per Capita.
- Carbon Intensity.
- Mixed Land Uses.
- Transportation Affordability.
- Benefits by Income Group.
- Land Consumption.
- Bicycle and Pedestrian Activity and Safety.
- Bicycle and Pedestrian Level of Service.
- Average Vehicle Occupancy.
- Transit Productivity.

For each measure, this section includes a description, a list of the decision-making phases in which it can be applied, a list of possible metrics, a brief discussion of analytical methods and data sources, and one or more examples of the measure in use.

Measure: Transit Accessibility

Measures the ability of people to reach destinations using public transportation

Description

Transit accessibility reflects the relative convenience of transit as a mode choice. It can be measured in terms of distance to transit stops or travel time on transit. Metrics typically emphasize the availability of transit where people live, where people work, and on routes that connect the two.

Both capital investments in transit and enhancements to transit operations can improve transit accessibility. The location of jobs and housing relative to transit services also has a major impact on transit accessibility. Higher transit accessibility can use energy more efficiently, reduce GHG emissions, improve air quality, and make transportation more affordable.

A transit accessibility measure can be easily adapted to account for social equity considerations. Transit tends to be an important mode of transportation for low-income populations, who are less likely to have access to a car. Transit accessibility metrics can be calculated specifically for low-income populations, as compared to the total population.

Application

- Land use visioning.
- Long-range transportation planning.
- Corridor studies.
- Programming.

Metrics

Individual metrics measure the share of jobs or population that fall within a given threshold of accessibility. Most accessibility metrics fall into one of the following two groups:

Distance to transit stops. These metrics capture the amount of jobs, population, trip origins, or trip destinations within a certain radius of a transit stop. The radius often represents a reasonable distance that people are willing to walk to and from transit stops, typically between ¼ mile and ½ mile. Examples include:

- Percent of daily/peak period trips (origins and destinations) starting or ending within ¼ mile of a transit stop.
- Percent of population and employment within 0.4 miles of transit.
- Households within five miles of park-and-ride lots or major transit centers.

Destinations accessible by transit. These metrics capture not just the accessibility of transit stops, but the connection that transit provides to various destinations. For example, a metric could capture the number of jobs accessible within a certain travel time. This type of metric incorporates the relationships of various land uses and the performance of the transit system. For example, a suburban housing development served by a bus route could largely fall into a threshold defined by distance to transit stops, but may not meet a threshold for destinations accessible by transit if it is located far from job centers. Examples include:

- Share of population with good transit-job accessibility (100,000+ jobs within 45 minutes).
- Number of households within a 30-minute transit ride of major employment centers.
- Percentage of work and education trips accessible in less than 30 minutes transit travel time.
- Percentage of workforce that can reach their workplace by transit within one hour with no more than one transfer.

Analytical Methods and Data Sources

To calculate transit accessibility metrics based on distance to transit stops, the following information is required:

- Data on regional trip origins and destinations (locations of population and employment).
- Data on the locations of transit stops.

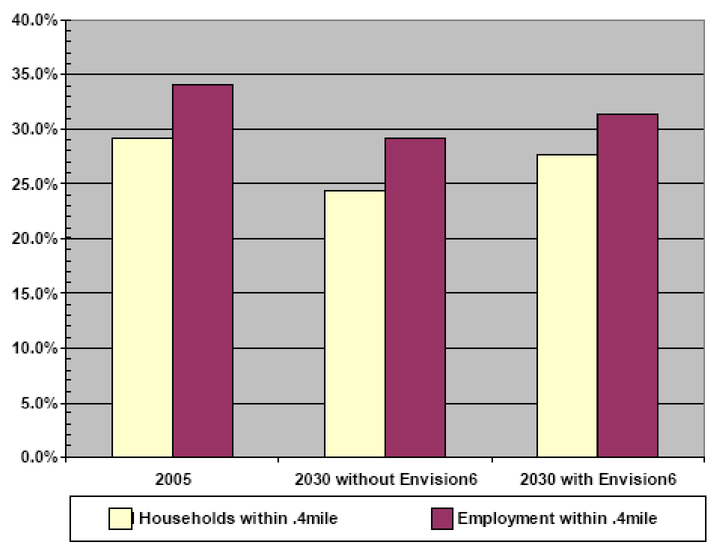
Defining a transit stop requires establishing a threshold for service frequency (e.g., 15-minute headways during peak periods). Thus, an agency needs information on transit service frequency in addition to stop locations. Identifying transit stops can be challenging when forecasting new bus service in areas of growth. Metrics based on distance to transit stops can be calculated through a spatial analysis of the above two data points, supported by Geographic Information Systems (GIS) software.

Calculating metrics based on destinations accessible by transit requires additional steps. A travel demand model incorporating a robust transit network must be used to estimate the travel time or distance between origins and destinations on the transit network.

Example

In its 2030 Regional Transportation Plan, the Atlanta Regional Council evaluated the share of population and employment within walking distance (0.4 miles) of a transit stop. Figure 4 provides the results of the analysis for the current year, which was 2005; 2030 without the strategies suggested by the plan; and 2030 with the implementation of the plan.[5] Because most growth is occurring on the periphery of the region, transit accessibility is projected to decline in the future under both alternatives. However, this decrease in transit access is smaller under the plan scenario (Envision6) than it is under the no-plan scenario.

Figure 4: Atlanta Regional Council – Share of Population and Employment within Walking Distance of Transit



The San Diego Association of Governments evaluated accessibility of work, college, and non-work destinations by mode in its most recent long-range transportation plan. Accessible work and college destinations were defined as those within 30 minutes of travel from home. Accessible non-work destinations were defined as those within 15 minutes of travel from home. Figure 5 shows the results of the analysis for the current year, which was 2006, and four future-year scenarios.[6]

The various "build" alternatives all improve future accessibility as compared to the business-as-usual, or "no build," scenario.

Figure 5: San Diego Association of Governments – Accessibility Measures

Goals and Performance Measures	Long Range Transportation Plan Scenarios				
	Current (2006)	Revenue Constrained (2030)	Reasonably Expected (2030)	Smart Growth RE (2030)	No Build (2030)
Percent of work and higher education trips accessible in 30 minutes in peak periods	61%	54%	56%	57%	53%
Percent of work and higher education trips accessible in 30 minutes in peak periods by mode					
Auto	65%	57%	58%	60%	55%
Transit	10%	13%	15%	16%	10%
Carpool	67%	64%	68%	70%	59%
Percent of non-work-related trips accessible in 15 minutes	66%	63%	63%	64%	62%
Percent of non-work-related trips accessible in 15 minutes by mode					
Auto	67%	63%	63%	64%	63%
Transit	4%	6%	7%	7%	4%
Carpool	68%	66%	66%	67%	64%

Measure: Bicycle and Pedestrian Mode Share

Measures the proportion of trips taken by bicycle and walking mode

Description

Bicycling and walking are core elements of a sustainable transportation system. Trips by bicycling and walking produce no emissions and let people work physical activity into their daily routines to improve their health and save money. Drivers who switch to walking and bicycling can reduce their expenditures on fuel and vehicle maintenance while helping to reduce traffic congestion. A safe and attractive environment for pedestrians can also help promote economic development by increasing foot traffic near local businesses and attracting tourists and other consumers.

Bicycle and pedestrian travel can be encouraged through investments in infrastructure (i.e., bicycle paths and lanes, sidewalks, crosswalks), supporting amenities (i.e., bicycle parking, benches), and educational and promotional programs. Opportunities for travelers to choose walking and biking increase when growth patterns provide more housing in close proximity to jobs, stores, schools, and recreational destinations.

Most pedestrian and bicycle trips are short—typically no more than two miles for walking trips and five miles for bicycling trips. As a result, improvements to bicycling and walking facilities can have a large impact on non-work trips (e.g., shopping, school, and recreational trips), which tend to be short. In addition, improved pedestrian connections to transit systems have the potential to divert long automobile trips to walking-plus-transit trips.

Application

- Land use visioning.
- Long-range transportation planning.
- Corridor studies.
- Programming.
- Performance monitoring.

Metrics

Bicycle and pedestrian mode share represents bicycle and pedestrian trips as a percent of trips by all travel modes. Typical metrics include:

- Bicycle mode share (bicycle trips divided by total trips).
- Pedestrian mode share (pedestrian trips divided by total trips).

Bicycle and pedestrian mode share can be calculated for all trip purposes, for work trips only, or for other trip purposes. It can cover peak-period travel or average daily travel.

Because bicycle and pedestrian mode shares are typically small, differences across plan or project alternatives may not be apparent. Rather than reporting mode share by alternative, it may be more illustrative to report the percentage change in non-motorized trips by plan alternative, as compared to a plan baseline.

Analytical Methods and Data Source

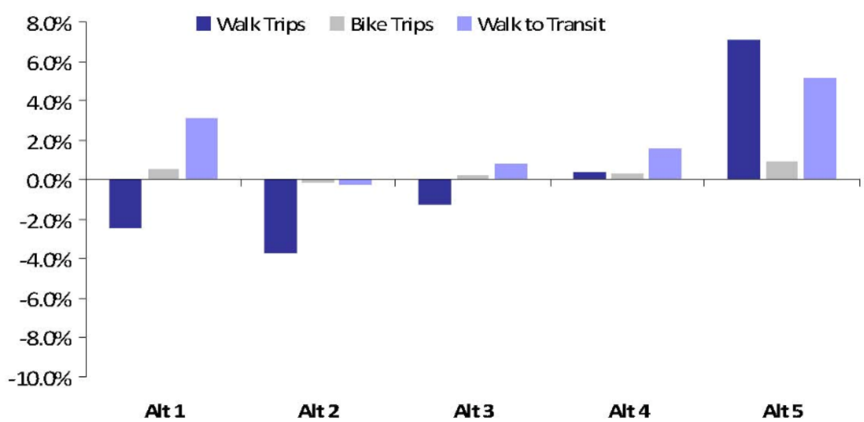
Reliable data on biking and walking trips are often difficult to obtain. For many transportation agencies, the only consistent data source is Census data, which reports only work trips and is likely to undercount non-motorized activity. Household travel surveys provide the most accurate measure of non-motorized travel, but they are typically expensive and conducted infrequently. In some regions (e.g., Portland, Oregon), an annual survey collects information about travel mode.

Some sophisticated regional travel demand models can produce relatively accurate forecasts of bicycle and pedestrian travel. However, most conventional travel models have only limited capabilities to forecast non-motorized mode shares. Activity-based travel models, which derive travel forecasts from information about activities that people perform, can significantly improve representation of bicycle and pedestrian trips.

Example

As part of the Puget Sound Regional Council's Transportation 2040 long-range planning process, the agency forecasted daily trips in 2040 by three non-motorized modes: walk, bike, and walk to transit. For each of the five plan alternatives, PSRC calculated the percentage change in trips by these modes as compared to a baseline scenario. (The baseline reflects existing transportation facilities plus future transportation investments that can be implemented with funds available through currently authorized transportation revenue instruments.) Figure 6 shows the results of the application of this performance measure. Alternative 5 (Reduce Emissions with Limited Highway Investments and Regional Tolling) results in the largest increase in walk and bike trips.[7]

Figure 6: Puget Sound Regional Council – Change in Walk and Bike Trips as Percent of Total Non-Motorized Trips from 2040 Baseline



Measure: VMT per Capita

Measures the amount of vehicle activity normalized by population

Description

Increases in VMT contribute to traffic congestion and air pollution, causing carbon dioxide and particulate matter emissions. Because of population growth and economic development, most regions cannot feasibly reduce absolute VMT. Reducing per capita VMT can help a region achieve air quality, climate change, and congestion reduction goals without penalizing it for population growth.

For regions interested in reducing transportation GHG emissions, an advantage of using a VMT metric is that VMT is more straightforward to analyze, since it does not account for vehicle fleet characteristics and fuel carbon content. Additionally, transportation planning agencies do not directly influence vehicle technologies and fuels, but their decisions can influence VMT. Measuring VMT also avoids the possibility that unexpected changes in vehicle and fuel characteristics would significantly affect a region's ability to meet its goals.

However, transportation GHG emissions are affected by factors other than VMT–vehicle fuel economy, fuel carbon content, and the efficiency of system operations–and the usefulness of VMT as a proxy for GHGs diminishes as vehicles and fuels become more efficient. In addition, a VMT metric will not capture the potential GHG benefits of transportation system management and operations strategies, such as lower speed limits, traffic signal improvements, and incident management programs that reduce traffic delay.

Application

- Land use visioning.
- Long-range transportation planning.
- Programming.
- Performance monitoring.

Metrics

VMT per capita metrics can be set up to analyze the activity of all vehicles. Alternatively, since demand management strategies have little influence on heavy-duty vehicles, metrics can focus on light-duty vehicles only. Some agencies have measured VMT per capita separately for work and non-work trips, or VMT per employee.

- VMT per capita.
- Light-duty VMT per capita.
- VMT per employee.

Analytical Methods and Data Sources

Nearly all MPOs develop or obtain forecasts of VMT and population as part of the long-range planning process, so calculating a VMT per capita metric is simple. Most MPOs used travel demand models to forecast VMT. Because the model networks do not include most local roads, VMT on these facilities must be estimated outside the model framework; local roadway VMT typically ranges from 5 to 20 percent of total metropolitan VMT.

Because of the limitations of travel demand models, they generally will not fully capture the effects of some strategies to reduce VMT, such as small-scale land use changes or improvements to bicycle and pedestrian facilities.

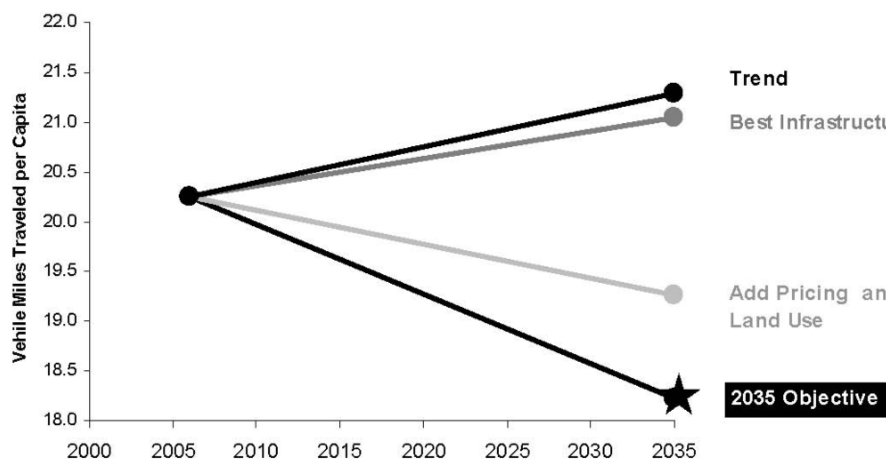
Some small and mid-size metropolitan areas are not covered by a travel demand forecasting model. Regions without travel demand forecasting models generally rely on calculations that involve spreadsheets to forecast future VMT. The methodologies range from very simple linear trend lines to more complex non-linear regression analyses.

Smaller MPOs may only estimate future traffic volumes for peak periods. Thus, estimating average daily VMT may require extrapolation of peak-period volumes.

Examples

In its most recent Regional Transportation Plan, the Metropolitan Transportation Commission (MTC – the San Francisco Bay Area MPO) established a goal of reducing daily per capita VMT by 10 percent by 2035. Baseline VMT per capita is forecast to grow 12 percent by 2035. Figure 7 shows that infrastructure investment packages had minimal effect on VMT, achieving a maximum of 1.4 percent reduction from the baseline.[8] The addition of aggressive land use and pricing strategies was found to be much more effective at reducing VMT per capita, although they still did not achieve the 2035 goal.

Figure 7: Metropolitan Transportation Commission (San Francisco Bay Area) – VMT per Capita under Investment and Policy Scenarios



Measure: Carbon Intensity

Measures the amount of carbon dioxide (CO_2) emitted from transportation per person

Description

CO_2 is the primary greenhouse gas emitted by transportation, accounting for 95 percent of transportation's impact on climate change. In gasoline-powered vehicles, CO_2 emissions are nearly directly proportional to the amount of fuel burned.

Transportation investments and compact development patterns can reduce carbon intensity by bringing activity centers closer together; by providing more robust transit, walking, and biking connections; and by encouraging carpooling. Shorter travel distance and fewer vehicle trips mean lower CO_2 emissions per capita. Some investments in freight systems can also reduce CO_2 emissions per capita.

Carbon intensity metrics are best applied at a regional scale. Individual transportation projects tend to affect carbon intensity beyond their geographical scopes. It is difficult to capture these broader changes at smaller scales of analysis.

Application

- Land use visioning.
- Long-range transportation planning.
- Programming.
- Performance monitoring.

Metrics

Carbon intensity is represented as CO_2 emissions per capita for all modes or individual modes of transportation. Examples include:

- Total transportation CO_2 emissions per capita
- Passenger transportation CO_2 emissions per capita
- Heavy-duty vehicle CO_2 emissions per capita

Analytical Methods and Data Sources

For on-road travel, there are two approaches to estimate emissions from VMT:

- CO_2 emissions can be estimated using a simple formula: CO_2 equals VMT divided by average fuel economy (miles per gallon) times carbon content of fuel (grams per gallon). This formula can be adapted to individual modes and vehicle classes, depending on the detail of the data available.
- Emissions models, can be used to estimate CO_2 emissions from travel demand inputs.[9] EPA's MOVES model is EPA's best tool for estimating greenhouse gas emissions from the transportation sector. MOVES2010a incorporates new car and light-truck greenhouse gas emissions standards affecting vehicle model years 2012 and later (rulemaking published May 7, 2010) and updates effects of corporate average fuel economy standards affecting model years 2008-2011. Thus, MOVES2010a or a subsequently released version should be used to estimate CO_2 emissions instead of an earlier EPA emissions model, such as MOBILE or an earlier version of MOVES. In California, the Air Resources Board's EMFAC, or EMissions FACtors model, provides similar functionality.[10]

If fleet mix, average fuel economy, and the mix of fuels are relatively constant, there is a near linear relationship between VMT and on-road CO_2 emissions. Thus VMT per capita can serve as a proxy for CO_2 emissions per capita under some circumstances. VMT is a poorer proxy for CO_2 emissions in the following situations:

- Traffic-smoothing measures, changes in vehicle technology, or changes in fleet mix are expected to improve average fuel economy.
- Changes in the type of fuel used are expected to change the carbon emissions of fuel per gallon.
- Some passenger travel is expected to shift from private vehicles to buses or trains, or freight is expected to shift from truck to train.

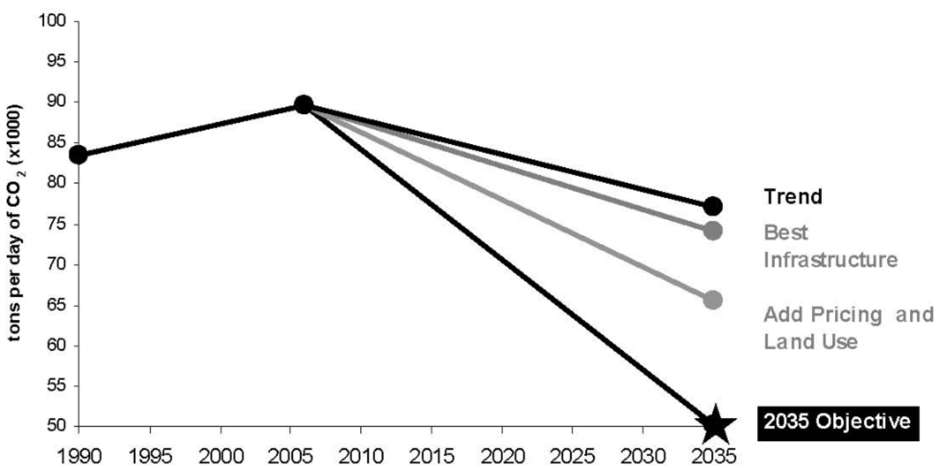
There is some debate about how to account for lifecycle GHG emissions of alternative fuels. Typically only the CO_2 emitted from the tailpipes of conventional gasoline and diesel vehicles is counted in transportation-related carbon intensity metrics; however, the "upstream" production and distribution of gasoline and diesel also emit CO_2, which is typically accounted for under stationary source metrics. Alternative fuels change both upstream emissions and tailpipe emissions. For example, electric vehicles emit no tailpipe CO_2, but the production of the electricity used to power them typically creates CO_2 emissions.[11] The decisions to include or exclude emissions from certain categories of fuel lifecycles can substantially affect the calculation of CO_2 emissions.

Examples

MTC established an ambitious target for CO_2 emissions from transportation in its most recent Regional Transportation Plan. Notably, the agency aimed to reduce not just CO_2 emissions per capita, but total CO_2 emissions, even with projected population growth. MTC tested several packages of infrastructure investments, along with transportation pricing policies and land use policies, for their impacts on CO_2 emissions.

Figure 8 shows the results of the final analysis.[12] Ultimately, improvements in vehicle fuel economy are expected to reverse the trend of rising CO_2 emissions, reducing total emissions from 90,000 tons per day in 2006 to 77,000 tons per day in 2035. The infrastructure investments in the plan will reduce CO_2 emissions an additional 1,000 tons per day, to 76,000. Additional land use and pricing measures were found to further reduce CO_2 emissions, although they did not achieve the 2035 target.

Figure 8: Metropolitan Transportation Commission (San Francisco Bay Area) – CO_2 Emissions per Day under Investment and Policy Scenarios



Note: The trend line from 2006 to 2035 is simplified. Passenger and light-duty vehicle fuel economy improvements required by state legislation are phased in between 2009 and 2030. CO_2 will continue to increase until about 2010, with a gradual decrease to 2035 as state standards phase in and the existing vehicle fleet turns over with cleaner vehicles.

Measure: Mixed Land Uses

Measures the proportion of residents living in locations with mixed land uses

Description

Conventional zoning often results in segregation of residential and commercial land uses. In contrast, mixed-use development locates land uses with complementary functions close together. Complementary uses may include housing, retail, offices, restaurants, and services—destinations that people travel to on a regular basis.

Locating activities closer together can reduce trip lengths, allowing trips to be made by walking and bicycling rather than by driving and increasing opportunities to combine trips. Individuals can drive to one destination, for example, and then walk to others once they have parked their car. Reducing vehicle trips can bring environmental and quality of life benefits. Furthermore, facilitating access to employment and shopping by walking and bicycling reduces the need to own a motor vehicle for personal mobility.

Application

- Land use visioning.
- Performance monitoring.

Metrics

Land use mix can be measured in numerous ways. The appropriate options for measuring land use mix depend in part on the scale of analysis (e.g., metropolitan, city/county, transportation analysis zone [TAZ], parcel).

One of the simplest metrics is the ratio of jobs to housing. At the metropolitan scale, the ratio of jobs to housing is usually close to 1, but cities and neighborhoods often have a large imbalance between jobs and housing, meaning that people have to commute farther to work. Land use visioning at the neighborhood scale can involve calculating an employment-to-dwelling unit ratio. Alternatives that shift this ratio closer to 1 are considered preferable, as this means jobs are available near where people live, reducing commute times and increasing accessibility by foot, bicycle, and public transit.

An index of population and employment mix in a study area can be calculated using the following equation, where ABS stands for absolute value:

$$1 - \text{ABS}\ \frac{\left(\frac{\text{Regional population}}{\text{Regional employment}} * \text{Study area pop.}\right) - \text{Study area emp.}}{\left(\frac{\text{Regional population}}{\text{Regional employment}} * \text{Study area pop.}\right) + \text{Study area emp.}}$$

The closer this index is to 1, the more the study area mirrors the region in terms of population and employment balance.

More complex measures of land use mix account for various land use types. For example, studies have developed an entropy index that measures the degree of balance across multiple land uses.[13] A dissimilarity index can measure how closely different land uses come into contact with one another.

Analytical Methods and Data Sources

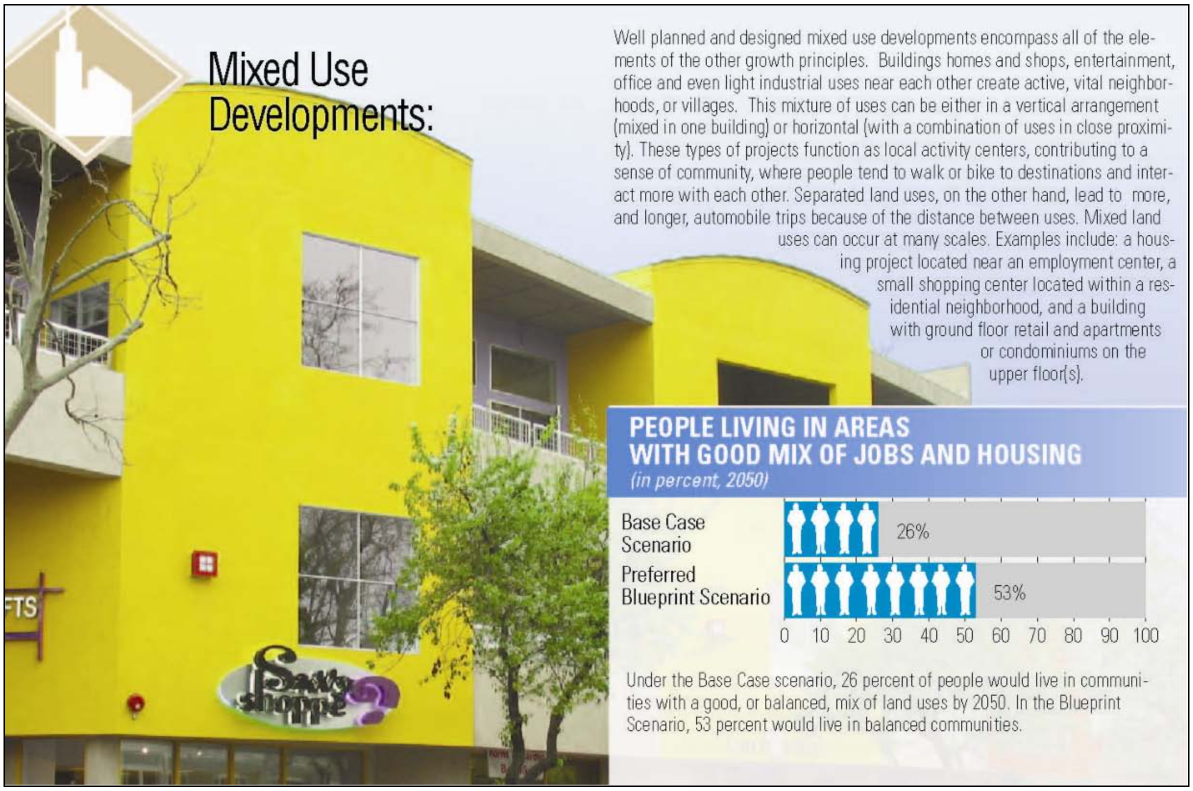
For analysis at a regional scale, most agencies use population and employment as proxies for land use type. Simple metrics of land use mixing use population and total employment, which are readily available to most MPOs for historic and forecast years at a variety of scales. Most complex land use mixing metrics might require data on different land use types, such as residential, retail, office, public, and industrial. Many MPOs will have data on retail versus non-retail employment, and some have employment data by major industry sector.

Analysis of land use mixing at a city, neighborhood, or parcel scale can often make use of data on acreage of land by use type. Such land use types may be consistent with local government zoning categories.

Examples

As part of its Blueprint land use visioning exercise, the Sacramento Area Council of Governments developed a mixed-use development measure based on the ratio of employees to dwelling units at the TAZ level. An optimum mix of jobs and housing is defined as a ratio of employees to dwelling units that is greater than 0.5 and less than 2.0. Figure 9 shows the comparison of the preferred Blueprint scenario versus the base land use scenario.[14]

Figure 9: Sacramento Area Council of Governments – Land Use Mix Measure from Blueprint Visioning



Measure: Transportation Affordability

Measures the cost of transportation relative to income

Description

Affordability captures the ability of transportation system users to pay for transportation. Whereas measures of transportation cost capture only the dollar amount that transportation system users pay, affordability puts cost in the context of income and other expenditures. A more affordable system is one that consumes a smaller share of users' incomes.

Transportation investments and compact development patterns can make transportation more affordable by reducing travel distances and providing less expensive options such as walking, bicycling, and transit. Changes in fares or tolls may have other cost implications for transit riders and motorists. An affordability measure tracks the financial impact of such actions on transportation system users.

Because affordability is particularly important for low-income and disadvantaged groups, this measure is often included in equity analyses. It can be calculated and compared across income groups.

Application

- Long-range regional transportation planning.
- Corridor studies.
- Programming.

Metrics

Transportation affordability is calculated as the annual cost of transportation relative to annual income. Alternatively, transportation costs can be calculated for different income groups to assess the direction and magnitude of forecasted changes in transportation costs.

Analytical Methods and Data Sources

Components of transportation cost can include:

- Public transportation fares
- Private vehicle ownership and operating costs
  - Fixed costs
    - Vehicle depreciation
    - Insurance
    - Finance charge
    - License fee
  - Variable costs (per mile or per trip)
    - Fuel and oil
    - Tires
    - Maintenance
    - User fees

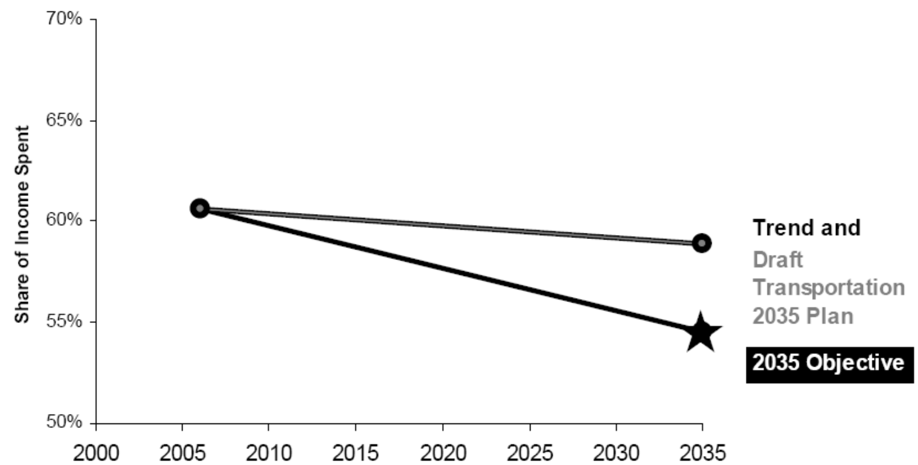
Some components of cost may be difficult to forecast using existing models.

Transportation affordability measures could also include a component representing housing costs. Including housing costs accounts for the trade-off that many households make between cheaper housing and longer travel distances. In practice, however, it is not possible to forecast zone-level changes in housing costs 20 or more years in the future with reasonable accuracy.

Examples

MTC included a transportation and housing affordability measure in its most recent long-range transportation plan. Without any reliable means to forecast housing cost, MTC merely held housing costs constant from 2006 to 2035. Figure 10 provides the results of the final analysis.[15] Affordability is expected to improve in the future, but the planned investments do not change affordability from the trend scenario. In a previous round of policy analyses, MTC found that pricing policies would increase the share of income spent on transportation and housing, while land use policies would decrease the share of income spent on transportation and housing.

Figure 10: Metropolitan Transportation Commission (San Francisco Bay Area) – Share of Income Spent on Transportation and Housing



Measure: Benefits by Income Group

Measures transportation plan benefits by income group

Description

The principles of environmental justice require that transportation plans do not disproportionately burden low-income and minority communities and that disadvantaged communities receive a fair share of the benefits of transportation system improvements.[16,17] Many transportation performance measures can be analyzed for different population groups to illustrate how transportation decisions will affect disadvantaged communities compared to other groups. A common approach is to calculate transportation benefits by income group.

Application

- Long-range regional transportation planning.
- Corridor studies.
- Programming.
- Environmental Review.

Metrics

Access to employment by income group. Employment accessibility measures generally count the number of jobs that are accessible within a given travel time from each TAZ. The travel time should be in the range of typical commute times. Calculations must be conducted separately for vehicle and transit trips if the results will be useful to assess conditions for people without vehicle access. In some cases, agencies have distinguished between access to professional and service-sector employment. Distinguishing between types of employment becomes particularly important in regions where there are concentrations of professional jobs without service jobs that provide opportunities for low-skilled workers.

Access to other destinations by income group. Agencies have evaluated the accessibility to other destinations that are particularly important to disadvantaged groups, such as health care, education, and recreational facilities.

Travel time by income group. Travel time performance measures indicate the average time needed for trips that people actually take or, in the case of future travel time, for trips that people are predicted to take. This measure may be more useful than accessibility when there are fewer central destinations. Average travel time may also be more meaningful than accessibility in assessing actual travel needs. If the jobs that exist near a low-income community require a high degree of professional training, the community could show a high degree of jobs accessibility. But the average travel time would better reflect the reality that those low-income individuals must travel long distances to reach jobs for which they are qualified. Travel time metrics for equity analysis include the following, each of which can be measured by mode and income group:

- Work trip travel time.
- Non-work trip travel time.
- Travel time to key destinations.
- Travel time for some specific trip types (shopping, recreation).
- Travel time to specific major activity centers.

Transportation service provision by income group. The provision of transportation service is another valuable measure for equity analysis. This measure is useful because it addresses conditions under the direct control of transportation agencies. Measures of service provision are also among the most tangible and easy-to-understand performance measures. They should, however, be combined with other measures such as the accessibility measure described above, since accessibility is the goal of service provision. Options for metrics include:

- Average distance to the nearest transit stop.
- Availability of nighttime service.
- Availability of low-cost transit options.
- Frequency of service.
- Degree of crowding.
- Number and quality of bus shelters.

Analytical Methods and Data Sources

Analysis of transportation plan benefits by income group typically requires classifying TAZs using average household income data. All trip productions from a given TAZ are then assumed to be representative of the average household income of that TAZ.

Employment accessibility metrics are calculated using zone-to-zone peak-period travel time by mode. Accessibility to other destinations may be calculating using peak or off-peak travel times, depending on the destination type. The location of destinations other than jobs may not be readily available to the transportation agency, but other agencies, institutions, or commercial associations may maintain such information. For example, county community service agencies may keep records on the size and location of all hospitals and clinics.

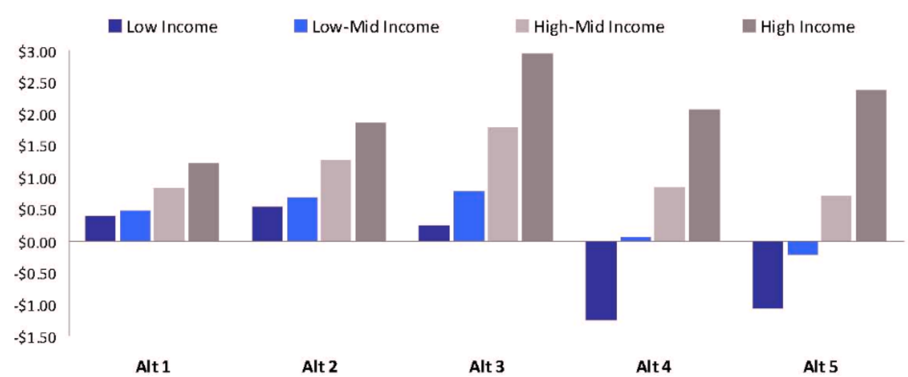
Calculating transit accessibility requires a travel demand model that includes a robust transit network to estimate the travel time or distance between origins and destinations on the transit network.

Metrics involving transportation service provision may require detailed information on transit service by route and zone, information that is available from service providers.

Examples

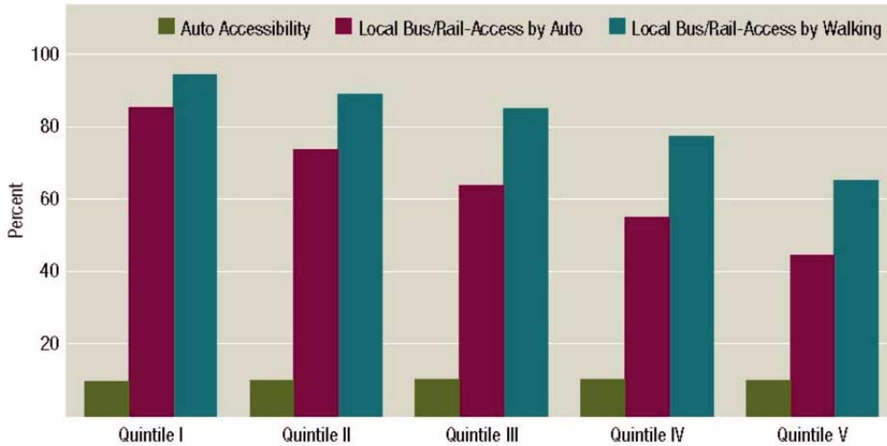
PSRC estimated the change in transportation costs (per work trip) in terms of the monetary value of reduced travel time, unreliability, vehicle operating costs, and other user costs. Work trips were divided into four income groups to show the distribution of benefits. Figure 11 shows these benefits (reduction in transportation costs) across the five plan alternatives, as compared to the 2040 Baseline scenario.[18] Compared to the baseline, improvements in system efficiency and expansion of travel alternatives reduce transportation costs for all users under Alternatives 1, 2, and 3. Because Alternatives 4 and 5 involve extensive new roadway pricing, they increase transportation costs for low-income residents compared to the 2040 baseline.

Figure 11: Puget Sound Regional Council – Transportation Benefits per Work Trip by Income Group (Change from 2040 Baseline)



The Southern California Association of Governments (the MPO for the Los Angeles region) analyzed access to local, state, and national parks by travel model and income quintile. For this analysis, they defined park accessibility as the percentage of park acreage reachable within a 30-minute off-peak travel time period via: 1) automobile; 2) local bus/rail reached by automobile; and 3) local bus/rail reached by walking. For transit travel time, both the waiting time and the on-board time are included. Figure 12 shows the finding that low-income residents would receive larger improvements in transit access to parks as compared to higher-income residents.[19]

Figure 12: Southern California Association of Governments – Improvements in Park Accessibility by Travel Mode and Income Group
(Plan vs. 2035 Baseline)



Measure: Land Consumption

Measures the amount of land consumed by new transportation infrastructure and/or new development served by new transportation infrastructure

Description

Compact development patterns and transportation investments that support these patterns use land more efficiently. Using land efficiently for development preserves farmland, open space, natural habitat, and watershed protection areas, which are important to communities for many reasons, including their scenic qualities, the economic activities they support, and their recreational value. These landscapes also conduct essential natural ecological functions, such as filtering pollutants from the air and water and reducing contaminated stormwater runoff.

Application

- Land use visioning.
- Long-range transportation planning.
- Corridor studies.
- Programming.

Metrics

Land consumption metrics can measure the amount of land affected by various types of development and can focus on impacts on particular types of natural lands. Examples include:

- Acreage of sensitive lands (e.g., parkland, habitat) on which new transportation infrastructure is built.

- Number of residential units and square feet of non-residential space near agricultural and natural resource lands.
- Number of lane miles of roadways, amount of square footage of buildings, and number of parking spaces in park-and-ride lots.
- Amount of new housing and jobs in greenfields.
- Acres of land consumed per residential unit.
- Acres of farmland converted to development.

Analytical Methods and Data Sources

Land consumption measures are often forecast as part of regional land use and transportation visioning exercises. Such exercises often use sketch planning tools to model development patterns and facilitate stakeholder input. Development alternatives can be matched with existing land uses in a GIS analysis to estimate what types of natural lands would be affected.

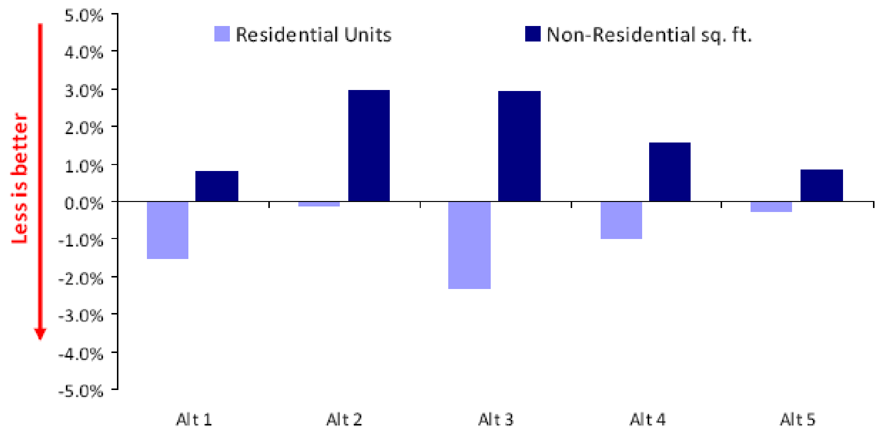
Land consumption can also be modeled in long-range transportation planning exercises. Ideally, in order to demonstrate meaningful differences between alternatives, planners should use a model that incorporates feedback between the transportation network and land development patterns. An integrated transportation and land use model can predict how greenfield sites might be developed if new roads are built that improve access to them.

To the extent that land use patterns are established prior to long-range transportation planning, alternative scenarios will show less variation in impacts on land consumption. In these cases, it may be more appropriate to assess the land consumption impacts only for transportation infrastructure.

Examples

PSRC evaluated the impact of its most recent plan on natural lands. The agency modeled the amount of development that would occur on parcels adjacent to agricultural and natural resource lands under five different plan alternatives. Figure 13 shows the impact of alternatives relative to a 2040 trend baseline.[20] All alternatives increase the amount of non-residential development and decrease the amount of residential development near natural resource and agricultural lands. Alternative 1 (Emphasize the Efficiency of the Existing System) and Alternative 5 (Reduce Emissions with Limited Highway Investments and Regional Tolling) create the least pressure on natural lands.

Figure 13: Puget Sound Regional Council – Development on Parcels in Proximity to Resource and Agricultural Lands
(Change from 2040 Baseline)



In 2004, the Mid-Ohio Regional Planning Commission (the MPO for Columbus, Ohio) conducted a visioning exercise to explore the impacts of alternative land use and transportation scenarios for a 2030 horizon year. The amount of new development in greenfield areas was one criterion used to assess alternatives. Figure 14 shows the results of the analysis.[21] Two scenarios reduced the amount of new jobs and housing in greenfields compared to the trend scenario, although they did not affect total jobs and housing in the region.

Figure 14: Mid-Ohio Regional Planning Commission—Comparison of Transportation and Land Use Alternatives

Scenarios	VMT vs. Current	Total Sq. Miles Developed	% New on Greenfields	
			Housing	Jobs
Trend	46%	1,543	84%	91%
Shifting Inward	40%	1,440	84%	91%
Shifting Inward with Increased Transit	31%	1,370	73%	61%
Aggressively Inward	21%	1,186	51%	22%

Measure: Bicycle and Pedestrian Activity and Safety

Measures the level of bicycle and pedestrian activity and safety in specific locations

Description

Unlike driving, bicycle and pedestrian activity is generally not measured in an accurate and consistent manner over time. As a result, it can be more difficult to identify locations for bicycle and pedestrian system improvements, to observe the effects of those improvements, and to justify additional investments.

This measure is used primarily for regional performance monitoring and can inform programming, corridor studies, and project-level environmental review. It can be used to monitor trends in bicycle and pedestrian activity in key corridors or across an entire region. When combined with crash data, it can provide a better measure of the locations of safety problems. Traditionally, bicycle and pedestrian crash data are reported as the number of incidents per location, without information on the level of bicycle and pedestrian activity in that location. This can lead to erroneous conclusions that low-activity locations are relatively safe and high-activity locations are relatively unsafe. By calculating a crash rate (crashes divided by bicycle or pedestrian counts), regions can better target locations for safety improvements.

Application

- Corridor studies.
- Programming (grant awards).
- Environmental review.
- Performance monitoring.

Metrics

The basic metrics for bicycle and pedestrian activity are simply volumes per unit of time, such as:

- Bicycles per day.
- Pedestrians per day.

As discussed above, accurate bicycle and pedestrian counts can be paired with crash data to assess safety. Measures of safety can consider exposure by calculating the rate of crashes per unit of volume, such as:

- Bicycle crashes per 1,000 cyclists.
- Pedestrian crashes per 1,000 pedestrians.

Analytical Methods and Data Sources

MPOs may not need to collect this activity data themselves. Cities, counties, and park districts often perform their own bicycle or pedestrian counts–sometimes systemwide to develop a bicycle or pedestrian plan, or sometimes at a single location as part of an impact analysis. By setting regional standards for counts and serving as a repository for them, the MPO can develop a large database of bicycle and pedestrian activity.

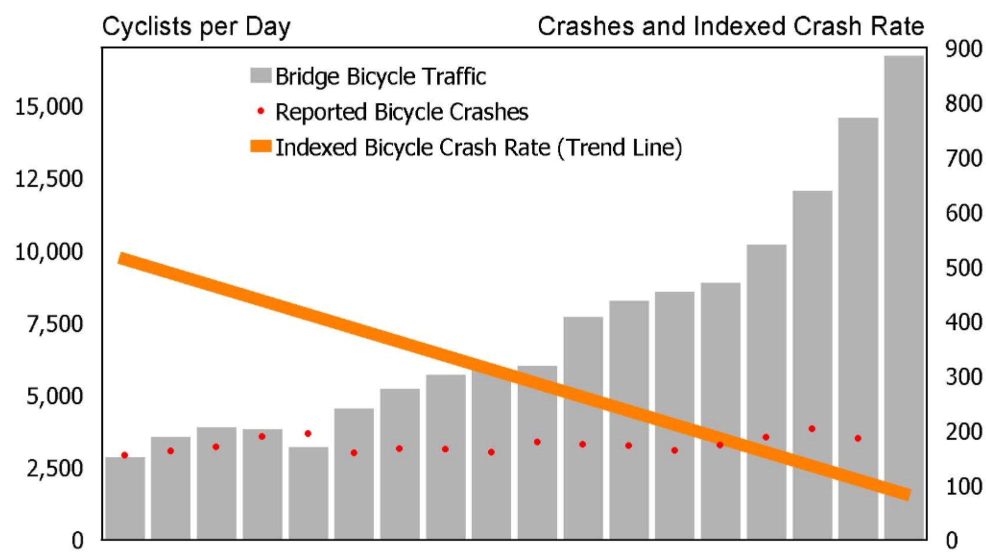
The National Bicycle and Pedestrian Documentation Project, an effort to promote consistency in data collection methods, has produced guidance on collecting bicycle and pedestrian data, including: [22]

- *Selection of count methods.* Manual and automatic counters can each be used and have different advantages and disadvantages.
- *Selection of count locations.* Screenline counts, which measure the number of bicyclists and pedestrians crossing a line “drawn” at a key location, are generally used to identify trends in bicycle and pedestrian volume. Intersection counts are done to develop crash exposure information and identify safety problems.
- *Selection of count dates.* Official national count/survey days (in September) are selected, with additional optional days in January, May, and July.
- *Selection of time of day.* At least 2 hours of count data is needed.

Example

Since 1991, Portland, Oregon, has conducted screenline bicycle counts on four main Willamette River bridges that connect downtown with many of the city’s residential areas. Through this consistent count program, the city has shown a remarkable increase in bicycling to and from downtown Portland. This growth in bicycle use has coincided with a more than three-fold increase in bikeway miles in the city. The city has also maintained data on bicycle crashes over this period, which have remained relatively constant. Using bridge bicycle activity as a proxy for citywide activity, Portland shows a declining bicycle crash rate (see Figure 15).[23]

Figure 15: City of Portland, OR – Bicycle Counts and Crashes on Four Main Bicycle Bridges



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Bridge Bicycle Traffic	2,850	3,555	3,885	3,830	3,207	4,520	5,225	5,690	5,910	6,015	7,686	8,250	8,562	8,875	10,192	12,046	14,563	16,711
Reported Bicycle Crashes	155	163	171	189	195	160	167	166	161	179	175	173	164	174	188	203	186	*
Indexed Bicycle Crash Rate (Trend Line)	544	459	440	493	514	354	320	292	272	298	230	210	192	196	184	168	128	*
Bicycle Fatalities	2	0	4	3	2	1	5	3	0	0	5	0	4	1	4	0	6	0

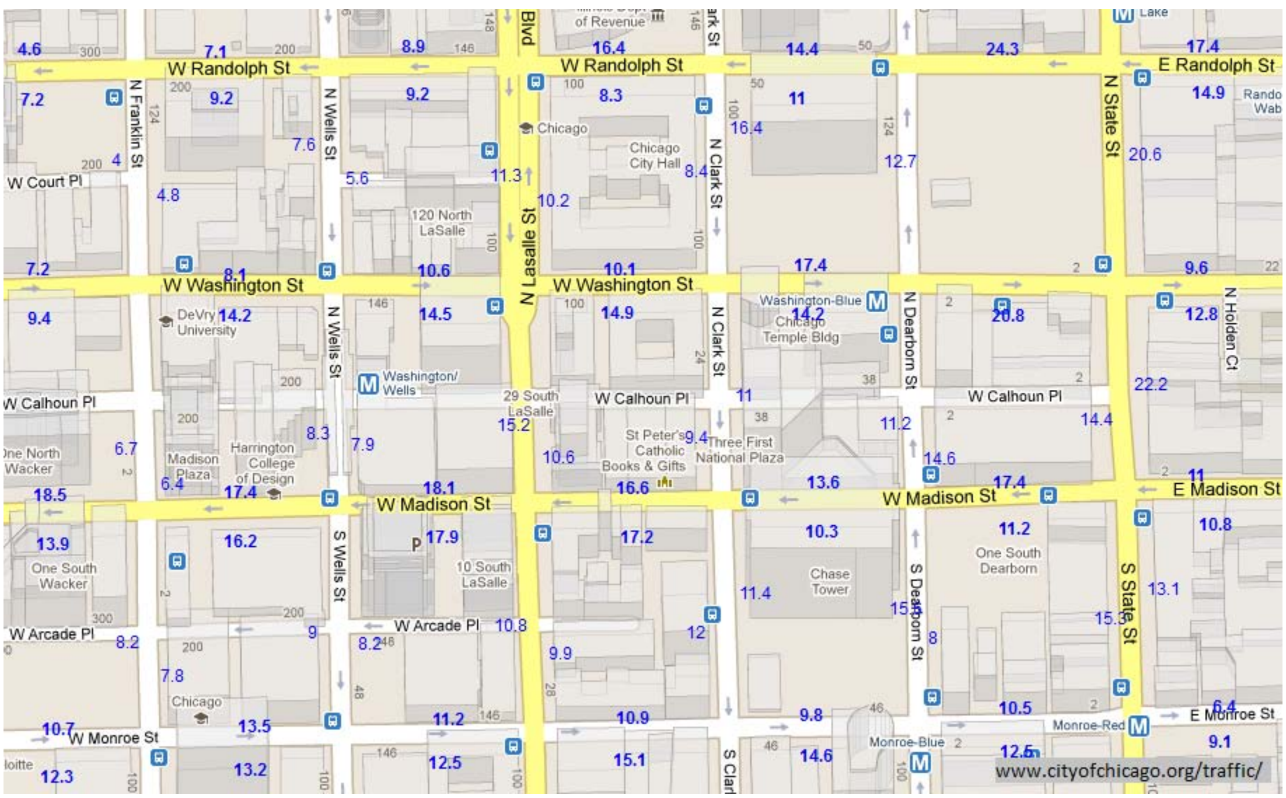
In recent years, Portland has significantly expanded its program of consistent collection of bicycle counts at non-bridge locations citywide. These counts have mostly been manual counts, taken by volunteer counters and city staff; the city also conducts several 24-hour automated pneumatic hose counts on some bridges and pathways. In 2009, bicycle counts were conducted at more than 100 locations (Figure 16).[24]

Figure 16: City of Portland, OR – 2009 Non-Bridge Bicycle Counts Compared with Prior Years

DISTRICT/ LOCATION	% CHANGE SINCE 2000/01	BASED ON # LOCATIONS	% CHANGE SINCE 2008	BASED ON # LOCATIONS
Citywide Total	190%	30	-4.6%	101
Central City (west side)	212%	6	1.5%	8
North	183%	4	-8%	12
Northeast	138%	5	-7%	14
Southeast	243%	7	-2%	21
East	na	na	3.5%	16
Northwest	81%	4	-8.5%	9
Southwest	161%	4	-11.5%	21

The city of Chicago, in partnership with the Chicago Metropolitan Agency for Planning, collects block-level pedestrian counts for much of the city's downtown area. The counts are available on the city's interactive web map, together with traffic counts and signal information. A sample map is shown in Figure 17.[25]

Figure 17: Chicago Department of Transportation – Block-Level Pedestrian Counts Over One Day, in Thousands (Sample)



Measure: Bicycle and Pedestrian Level of Service

Measures the quality of service from the perspective of a bicyclist or pedestrian

Description

Historically, level of service (LOS) measures for bicycles and pedestrians, if used at all, reflected a traffic engineering perspective that placed a high value on speed and minimizing delay. Research has shown that other factors are much more important to the quality of service for bicyclists and pedestrians, such as automobile traffic volumes and perceptions of safety. The Transportation Research Board's *2010 Highway Capacity Manual*, which contains guidelines for calculating the capacity and quality of service for various types of roads, significantly revised the approach to bicycle and pedestrian LOS to reflect this user perspective.[26]

Because of the data required, bicycle and pedestrian LOS cannot be assessed for all the roadways in a region. However, MPOs can play an important role in data collection and in organizing and presenting bicycle and pedestrian LOS results for select facilities.

Application

- Corridor studies.
- Programming (grant awards).
- Environmental review.
- Performance monitoring.

Metrics

- Bicycle LOS (grade A – F).
- Pedestrian LOS (grade A – F).

Analytical Methods and Data Sources

Methods for calculating bicycle and pedestrian LOS are documented in reports such as the National Cooperative Highway Research Program's *Report 616: Multimodal Level of Service Analysis for Urban Streets* and the Florida Department of Transportation *Quality/Level of Service Handbook.*[27,28] The *2010 Highway Capacity Manual* also includes these methods.[29]

In general, bicycle LOS focuses on rating the comfort and perceived safety of an adult cyclist. It requires information such as roadway width, bike lane widths and striping combinations, traffic volume, pavement surface conditions, motor vehicles speed and type, and on-street parking.

Similarly, pedestrian LOS evaluates walking conditions from the point of view of perceived comfort and safety. It requires information such as roadway/street width and striping combinations, presence of a sidewalk, traffic volumes, motor vehicles speed, and on-street parking.

Figure 18 shows typical input parameters for calculating bicycle and pedestrian LOS.

Figure 18: Bicycle and Pedestrian LOS Input Parameters
Image source: ICF International

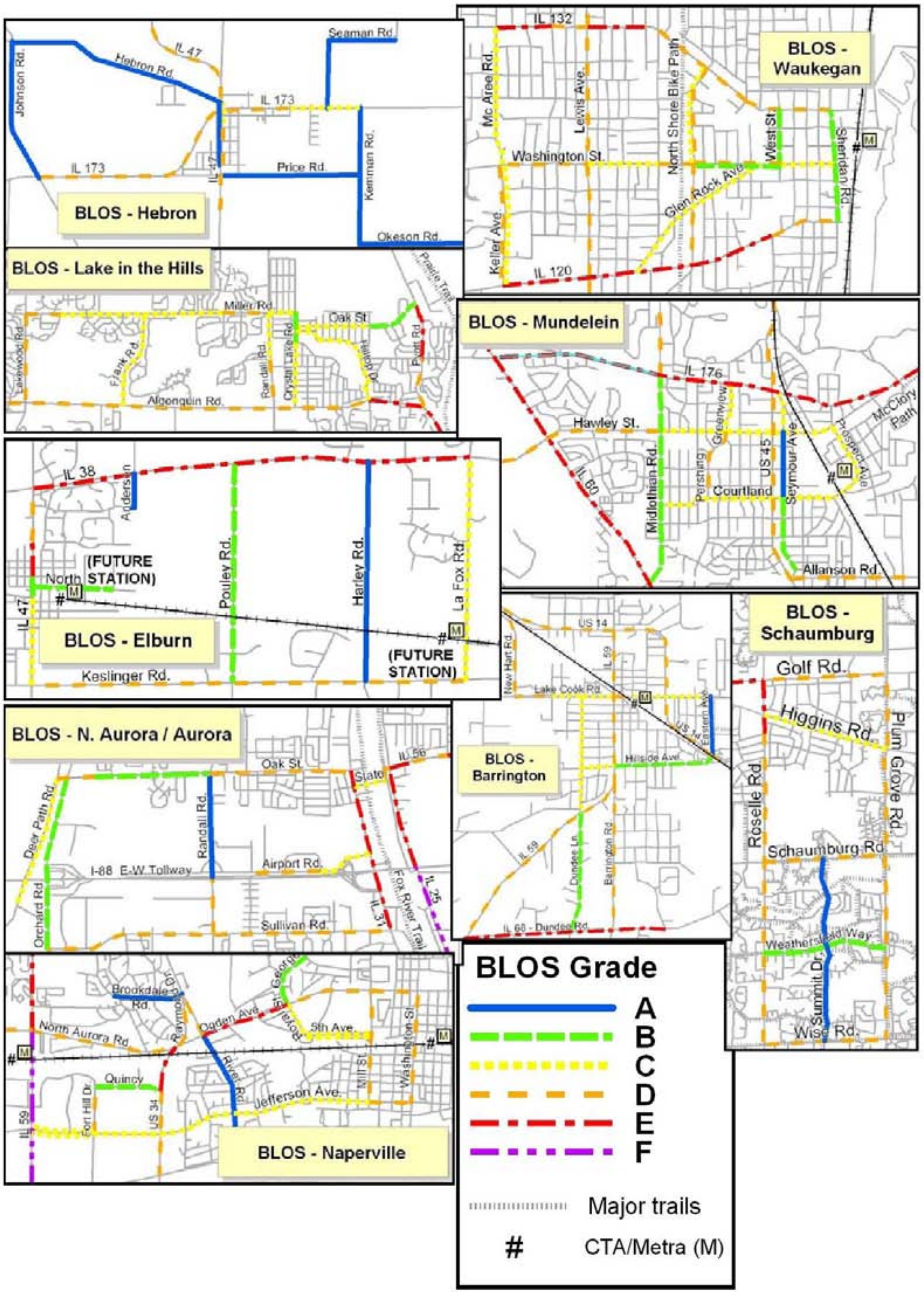
Bicycle LOS Input Parameters	Pedestrian LOS Input Parameters
ADT - Traffic volume	ADT - Traffic volume
Directional, Peak-to-daily, and Peak Hour Factors	Directional, Peak-to-daily, and Peak Hour Factors
Number of through lanes	Number of through lanes
Speed limit	Traffic speed
Percentage of traffic that is heavy vehicles	Buffer width
Surface condition rating	Sidewalk width
Width of outside lane	Width of outside lane
On-street parking permitted, percentage occupied parking	On-street parking permitted, percentage occupied parking
Pavement width to the right of outside lane stripe (including paved shoulder, parking area, bike lane)	Pavement width to the right of outside lane stripe (including paved shoulder, parking area, bike lane)
Parking width (to the right of a bike lane)	Existence and spacing of trees

Ideally, LOS for automobiles, transit, bicyclists, and pedestrians are all reported for a street as part of a multimodal LOS.

Examples

The Chicago Metropolitan Agency for Planning developed bicycle and pedestrian LOS measures for selected communities across the region as part of the region's comprehensive bicycle and pedestrian plan. Figure 19 shows a sample of these results.[30]

Figure 19: Chicago Metropolitan Agency for Planning – Bicycle LOS for Sample of Communities



Measure: Average Vehicle Occupancy

Measures the ratio of passengers to vehicles on the roadway (the average number of people in each vehicle)

Description

Average vehicle occupancy (AVO) (also called average vehicle ridership or vehicle occupancy rate) captures the number of people traveling in each vehicle. AVO is a simple indicator, with broad implications for the sustainability of the transportation system. A higher AVO indicates that more people are traveling in fewer vehicles. As a result, the existing roadway capacity can handle more passenger travel with less congestion. More passengers per vehicle also means that per passenger emissions are lower. Finally, a higher AVO suggests a more affordable transportation system, since sharing a ride is typically cheaper than driving alone.

A wide range of policies and programs can increase AVO. Preferential treatment for carpools and vanpools, such as high-occupancy vehicle (HOV) lanes and preferred parking, encourages ridesharing. Programs that help people find a shared ride to a common destination, such as ride-matching websites, also make carpooling easier and more attractive. Transportation pricing measures, such as tolls and parking fees, encourage carpooling by increasing the price of driving alone. Improving transit service can also increase AVO if transit vehicles are included in the calculation.

Application

- Land use visioning.
- Long-range transportation planning.
- Corridor studies.
- Programming.
- Performance monitoring.

Metrics

AVO is measured as the number of passengers traveling on a roadway segment or network divided by the number of vehicles traveling on the segment or network. Agencies may define the numerator and denominator differently depending on their goals. For example, the Mid-America Regional Council (MARC) in the bistate Kansas City region calculates AVO as the average number of occupants in private, passenger vehicles (e.g., automobiles, vans, minivans, pick-up trucks, and motorcycles). Other agencies include buses and bus passengers in the calculation.

AVO can be calculated at almost any temporal or geographical scale. MPOs commonly focus on AVO during peak travel periods (commute hours) and may estimate AVO on particular corridors in addition to regionwide AVO.

Analytical Methods and Data Sources

For monitoring purposes, AVO is typically estimated by sampling data from one of two sources:

- *Travel surveys.* Travel surveys administered at the household level or by employers can capture modal travel patterns for particular trips or trip purposes.
- *Vehicle and passenger counts.* Vehicle and passenger counts can be gathered from a combination of manual observation and automatically collected data along key corridors or at cordon points.

For forecasting purposes, many travel demand models estimate changes in AVO in response to transportation investments and policies. A mode choice component is required. In addition, several off-model analysis packages can be used to predict the impact of transportation strategies on AVO. For example, both EPA's COMMUTER model and the Center for Urban Transportation Research's TRIMMS model estimate the impact of employer-based financial incentives and other programs on carpool and vanpool mode share.[31,32] AVO can be derived from mode share figures, provided that the average number of occupants per carpool, vanpool, and bus is also known. A sample calculation is provided below:

AVO = (% carpool trips * avg. carpool occupancy) + (% SOV trips *1) + (% vanpool trips * avg. vanpool occupancy) + (% bus trips * avg. bus occupancy)

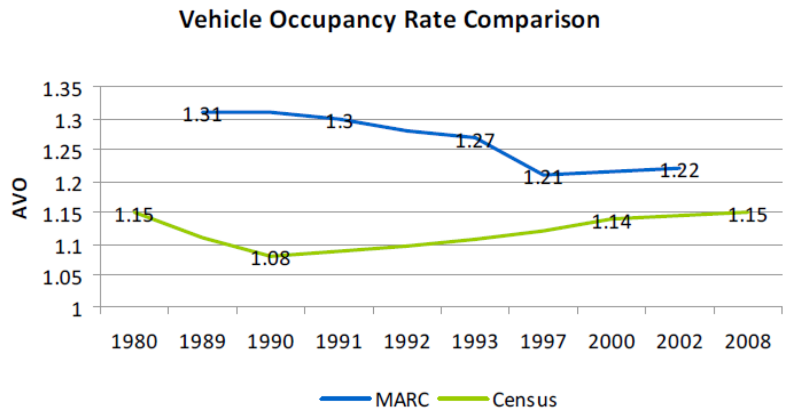
This methodology works best for smaller analytical units such as a work site or a corridor, where travel characteristics such as mode share, trip length, and parking costs are more homogeneous. For a larger analysis area, the change in AVO would more appropriately be calculated using a regional travel demand model.

The COMMUTER model can be used to estimate the change in travel activity, and then emission factors from EPA's latest emission factor model, MOVES, could be applied. Emission factors within the COMMUTER model are based on an older emission model and thus should not be used. COMMUTER and TRIMMS do not estimate changes in vehicle occupancy for individual modes.

Example

MARC included Vehicle Occupancy Rate as a performance measure in its long-range transportation plan, *Transportation Outlook 2040*. The agency set a goal to increase AVO from its 2002 baseline of 1.22. As described above, MARC calculates AVO as the average number of occupants in private, passenger vehicles. MARC sampled occupancy rates during weekday peak periods in an effort to focus on commute trips, but some non-commute trips were inevitably captured. Data for the 2002 study that established the baseline were collected by counting the total number of occupants in a sample of vehicles passing selected sites throughout the Kansas City region (Figure 20).[33]

Figure 20: Mid-America Regional Council (Kansas City region)—Average Vehicle Occupancy Trends



Measure: Transit Productivity

Measures the average number of riders on transit vehicles

Description

Transit productivity is a measure of return on investment in the transit system. It measures how much travelers use the transit service provided in a region. Many local buses in the United States travel with few passengers, suggesting that transit systems are not providing transportation benefits consistent with their capital and operating costs.[34] Having more passengers on each bus generates more revenue for transit agencies and can result in better air quality and less congestion.

Transit productivity is increased by more closely matching transit capacity (supply) with transit demand. Transit demand can be stimulated through a variety of policies and programs, including marketing and outreach to customers and providing financial incentives to use transit. Investments in the transit system that improve the overall performance of transit and locate transit nodes in high-density areas also stimulate demand for transit. Conversely, reducing transit service in areas with low demand can improve the ratio of passengers to capacity, but reducing service may conflict with key goals of transit agencies, such as providing a minimum level of service in low-income communities.

Application

- Land use visioning.
- Long-range transportation planning.
- Corridor studies.
- Programming.
- Performance monitoring.

Metrics

Transit productivity is the ratio of passenger travel to transit service provided. Metrics can take several forms, including:

- Average weekday transit boardings per vehicle revenue hour.
- Average transit boardings per vehicle revenue mile.
- Average annual transit boardings per route mile.
- Passenger miles traveled per vehicle revenue mile.

Transit productivity is typically measured at either the corridor level or the system level. At the corridor level, productivity is often forecast for individual transit investments as part of long-range planning and funding procedures. At the system level, transit productivity can be used to evaluate long-range plan alternatives, including modal alternatives.

The return on transit investments has historically been subject to a higher level of scrutiny than investments in other modes. For example, DOT requires that transit projects applying for federal funding must be evaluated for cost effectiveness, defined as project cost per hour of projected user (i.e., travel-time) benefits. No such evaluation is required for general-purpose roadway investments. Without metrics that can be used to compare investments between different modes, there is a possibility of over-investment in one mode versus another.

Other return on investment metrics could allow comparison between different modes of travel. For example, person trips per dollar of public and private expenditure could be used to evaluate transit, roadway, bicycle, and pedestrian infrastructure investments at the network level. However, this metric might not be informative when applied to long-range plan alternatives because federal planning statutes require that MPOs hold total person trips constant across plan alternatives. To date, few MPOs have used a multimodal return on investment measure.

Analytical Methods and Data Sources

Forecasting transit productivity requires the use of a travel demand model with a mode choice component. For a systemwide evaluation, a typical model automatically outputs both boardings (unlinked trips) and passenger miles traveled. To evaluate individual investments, the model automatically outputs boardings along each corridor. Additional calculation steps are required to allocate passenger miles traveled to each corridor.

For performance monitoring, systemwide transit productivity can be calculated from data that transit agencies report annually to the National Transit Database. The database contains statistics on number of boardings (unlinked trips), vehicle revenue hours, vehicle revenue miles, passenger miles traveled, and route miles by transit mode for each agency in the United States. Some information is also available by time of day. Transit agencies may also collect more detailed data on the performance of individual routes. Typically, transit agencies estimate demand-side variables using a combination of automatic passenger counts and rider surveys. Supply-side data are recorded in operating statistics.

Some MPOs use transit ridership as a performance measure in their long-range plans. In order to reflect transit's return on investment, transit productivity can be easily calculated from transit ridership by dividing by transit supply. Transit supply assumptions are inherent in the ridership forecasting model.

Example

Metro, the MPO for Portland, Oregon, included transit productivity as a performance measure in its 2035 Regional Transportation Plan. The metric used was average weekday (AWD) transit boardings per revenue hour. Productivity was forecasted to increase from 2005 to 2035 even without additional investments in the transit system. Under the fiscally constrained investment scenario (Federal Priorities System), transit productivity would increase an additional 7 percent over the no-build scenario (Figure 21).[35]

In addition to using transit productivity as a measure to evaluate investment alternatives, Metro has established a system monitoring plan that includes transit productivity as a performance measure. Transit productivity will be measured periodically for each of 24 designated corridors, and a system performance report will be prepared every two years. The performance report will inform the allocation of regional flexible funds.

Figure 21: Portland (OR) Metro – Transit Productivity Evaluation

Transit productivity	2005 Base Year	2035 No Build	2035 RTP Federal Priorities System	2035 RTP Investment Strategy
AWD transit boardings/ revenue hour*	65	109	117	117

*For the entire region including Clark, Clackamas, Multnomah and Washington counties

4. Applications of Sustainable Transportation Performance Measures

Transportation agencies have a variety of opportunities to apply performance measures to protect the environment, spur economic development, and promote healthy communities. This section describes six examples of how MPOs have applied sustainable transportation performance measures.

Long-Range Plan: Identifying Vision, Goals, and Targets

Performance measures help decision-makers assess how transportation policies and investments contribute to achieving regional goals. The selection of performance measures should follow directly from a region's vision, goals, and objectives.

Many long-range transportation plans begin with adopting a vision. A vision statement articulates a region's aspirations for the transportation system in a few sentences or paragraphs. Written in clear, simple language and using well-defined terms, a vision statement typically includes ambitious, but not unrealistic, aspirations.

Goals are more specific and directed than vision statements. While the vision describes an end-state, goals describe paths of action that lead to the vision. Figure 22 shows the transportation vision adopted by the Mid-America Regional Council and the nine transportation goals that are the foundation for the region's 2040 long-range transportation plan.[36]

Figure 22: Mid-America Regional Council – Vision and Goals in the Transportation Outlook 2040 Plan

Regional Vision

Greater Kansas City is a sustainable region that increases the vitality of our society, economy and environment for current residents and future generations.

↓

Transportation Vision

A safe, balanced, regional, multimodal transportation system that is coordinated with land use planning, supports equitable access to opportunities, and protects the environment.

↓

Transportation Goals

Accessibility – Maximize mobility and access to opportunities for all area residents.

Climate Change and Energy Use – Decrease the use of fossil fuels through reduced travel demand, technology advancements and a transition to renewable energy sources.

Economic Vitality – Support an innovative, competitive 21st century economy.

Environment – Protect and restore the region's natural resources (land, water and air) through proactive environmental stewardship.

Place Making – Coordinate transportation and land-use planning as a means to create quality places in existing and developing areas and to strengthen the quality of the region.

Public Health – Facilitate healthy, active living.

Safety and Security – Improve safety and security for all transportation users.

System Condition – Ensure transportation system is maintained in good condition.

System Performance – Manage the system to achieve reliable and efficient performance.

↓

Transportation Objectives

Each goal in the MARC plan was further defined by a set of objectives. For example, MARC identified the following six objectives under the goal of "Place Making":

- "Create places that are walkable and pedestrian friendly.
- Create places that support density and integrate multiple land uses (residential, commercial, office, etc.
- Create places that support a range of lifestyle and transportation options (transit, bicycle, auto, etc.).
- Create places that maximize the use of existing infrastructure through infill, redevelopment, and increased density.
- Create places that preserve and leverage the natural environment.
- Create places that are attractive, built to last, and integrated with their surroundings."

Once goals have been established, some regions have adopted performance targets related to the goals. These performance targets are numerical benchmarks to assess how well the long-range transportation plan achieves the goals and vision. For example, Figure 23 shows 10 performance targets included in Portland Metro's long-range transportation plan.[37] These targets are intended to provide policy direction for the development of the plan's investment strategy.

Figure 23: Portland (OR) Metro – 2035 Regional Transportation Plan Performance Targets
Image source: ICF International

Topic Area	Target
Safety	By 2035, reduce the number of pedestrian, bicyclist, and motor vehicle occupant fatalities plus serious injuries each by 50% compared to 2005.
Congestion	By 2035, reduce vehicle hours of delay (VHD) per person by 10% compared to 2005.
Freight reliability	By 2035, reduce vehicle hours of delay truck trip by 10% compared to 2005.
Climate change	By 2035, reduce transportation-related carbon dioxide emissions by 40% below 1990 levels.
Active transportation	By 2035, triple walking, biking, and transit mode share compared to 2005.
Basic infrastructure	By 2035, increase by 50% the number of essential destinations accessible within 30 minutes by trails, bicycling and public transit or within 15 minutes by sidewalks for all residents compared to 2005.
Clean air	By 2035, ensure zero percent population exposure to at-risk levels of air pollution.
Travel	By 2035, reduce vehicle miles traveled per person by 10% compared to 2005.
Affordability	By 2035, reduce the average household combined cost of housing and transportation by 25% compared to 2000.
Access to daily needs	By 2035, increase by 50% the number of essential destinations accessible within 30 minutes by bicycling and public transit for low-income, minority, senior, and disabled populations compared to 2005.

The use of performance measures or targets in the visioning stage of long-range planning can help elected officials and stakeholders to understand the potential benefits of emphasizing different policy and investment priorities. For example, MPOs have applied performance measures to illustrate the potential to reduce VMT through "levers" such as land use, pricing, and aggressive transit expansion. Typically, a visioning exercise does not apply the fiscal constraints that will ultimately be included in an adopted transportation plan.

Long-Range Plan: Project Performance Assessment

Performance measures can be used to evaluate individual projects being considered for inclusion in a long-range transportation plan. This is the best opportunity to ensure that the final plan includes projects that best support the region's vision and goals. However, quantitatively evaluating individual projects can be time consuming and may require technical capabilities not available to every transportation agency. As a compromise, agencies can apply quantitative evaluation to only those projects with the largest cost and greatest regional significance, while using qualitative assessment for all projects.

The Metropolitan Transportation Commission applied a quantitative and qualitative performance assessment to projects considered for the region's 2035 long-range transportation plan. The overall purpose of this assessment was to identify outliers—those projects that most strongly supported the plan's goals and objectives and those that most notably did not. The results of the assessment helped to guide the commission in making the trade-offs necessary to develop the plan, but it was not the only factor used to select projects. The MTC recognized that the performance assessment could not capture and weigh all relevant policy considerations, so local priorities could outweigh performance in some cases. The commission allowed exceptions after receiving formal explanations for such projects.

Approximately 700 projects were submitted for consideration in MTC's 2035 plan. MTC applied the quantitative evaluation to approximately 60 projects, most of which had areawide impacts and costs of more than $50 million. While this sub-set included less than 10 percent of the projects submitted, it made up roughly three-quarters of the discretionary investments in the plan. The projects selected for quantitative evaluation included major highway and transit projects as well as several regional investment programs, such as a regional bicycle network and the Transportation for Livable Communities program, which supports transportation projects that help revitalize downtown areas, commercial cores, and other existing neighborhoods. Figure 24 shows the quantitative project evaluation measures and the plan performance objectives addressed by each.[38] The benefit-cost ratio is a composite measure that includes travel time, user cost, emissions, and safety components.

Figure 24: Metropolitan Transportation Commission (San Francisco Bay Area) – Quantitative Project Evaluation Measures
Image source: ICF International

Measures	Plan Performance Objective
Benefit-Cost Ratio (monetized), reflecting: ▸ Recurrent delay (vehicle hours) ▸ Non-recurrent delay (vehicle hours) ▸ Transit travel time [1] ▸ Particulate matter emissions (PM2.5 and PM10) ▸ Carbon dioxide emissions ▸ Fatal and injury collisions ▸ Direct user costs (vehicle operating and, in some cases, auto ownership costs) ▸ Public and private cost savings from performing on-time maintenance [2]	Reduce Congestion, Reduce Emissions, Reduce Collisions and Fatalities
Reduction in VMT and cost per VMT reduced	Reduce Vehicle Miles Driven
Reduction in CO_2 emissions and cost per ton reduced	Reduce Emissions
Cost per low-income household served by transit (trial measure) [3]	Improve Affordability

Notes: 1) For HOV and HOT projects only; 2) For maintenance programs only; 3) For transit projects only.

MTC also performed a qualitative performance assessment for all projects submitted for plan inclusion. The agency determined that presenting an assessment for each of 700 individual projects would result in "information overload," so projects were grouped into 21 types. Each project type was then assessed in terms of how well it supported the plan goals. Figure 25 lists the criteria used to make this determination.[39] Each project type was judged to "strongly support," "support," or be "neutral toward" the criteria associated with each goal. MTC then tabulated the number of plan goals supported by each project type. All project types supported at least one goal; no project type "strongly supported" all five goals. The agency also calculated the total cost of projects supporting one goal, two goals, three goals, or four goals.

Figure 25: Metropolitan Transportation Commission (San Francisco Bay Area) – Project-Level Qualitative Assessment Criteria
Image source: ICF International

Plan Goals	Criteria for Determining Support
Maintenance	Advances maintenance of the existing transportation system
Congestion Relief (Reliability and Efficient Freight Travel) [1]	Improves freight mobility Improves transit mobility, effectiveness, or efficiency Improves local mobility or circulation Completes a critical transportation gap (geographic or temporal) Institutes or enables a new user-based pricing program Implements technology-based operations or traveler information Improves roadway safety
Emissions Reduction	Provides an alternative to driving alone Improves transit mobility, effectiveness, or efficiency Marketing, education and incentive programs that encourage mode shift away from driving alone or during peaks
Focused Growth	Located within a proposed or planed priority development area Connects two priority development areas
Access and Safety (non-motorized) [2]	Provides a transit alternative to driving on a future priced facility Provides an alternative to driving alone Improves access for youth, elderly, and disabled persons Improves safety for pedestrians and cyclists Reduces transportation or housing costs for low-income households

Notes: 1) Includes roadway safety; 2) Includes affordability for low-income households and non-motorized safety.

Long-Range Plan Evaluation

When a draft transportation plan has been developed, performance measures can be used to assess key system supply-and-demand characteristics. These measures should relate to the plan goals and objectives established early in the process. While this stage in the plan development may be too late to meaningfully influence project selection, applying performance measures allows the agency to evaluate the plan as a whole and sets the stage for future planning activities.

Figure 26 shows a sample of performance measures used to assess the 2031 regional transportation plan of the Central Lane MPO (Eugene-Springfield, Oregon).[40] A total of 24 performance measures were used to evaluate the plan, with comparisons to 2004 existing conditions. These measures confirmed that the plan was consistent with many of the region's sustainability objectives, including the expansion of walking and bicycling facilities and an increase in the number of people who use them.

Figure 26: Central Lane MPO (Oregon) – Summary of Sample Performance Measures
Image source: ICF International

Category	Key	Description	2004 Conditions	2031 Financially Constrained Plan	
			Amount	Amount	% Change
VMT and Trip Length	PM5b	Internal VMT/Capita	12.11	12.49	3.2%
	PM6	Average Trip Length (miles)	3.60	3.74	3.9%
	PM7	% Person Trips Under 1 Mile	14.8%	16.1%	8.8%
Mode Shares - All Trips	PM8a	Walk	9.2%	9.8%	6.3%
	PM8b	Bike	3.5%	3.9%	11.8%
	PM8c	Transit	2.1%	2.5%	16.4%
	PM8d	Shared Ride (2 or more)	41.3%	42.0%	1.6%
	PM8e	Drive Alone	43.9%	41.9%	-4.5%
	PM8f	% Non-Auto Trips	14.8%	16.1%	9.0%
	PM8g	Person Trips per Auto Trip	1.65	1.67	1.2%
System Characteristics	PM15	Ratio of Bikeway Miles to Arterial and Collector Miles	59%	86%	45.8%
	PM17	% of Households Within 1/4 Mile of a Transit Stop	83%	83%	0.0%
	PM18	Transit Service Hours per Capita	1.30	1.17	-10%
	PM21	Bikeway Miles	223.4	305.5	37%
	PM22	Priority Bikeway Miles	27.3	62.3	128%

Corridor-Level Evaluation

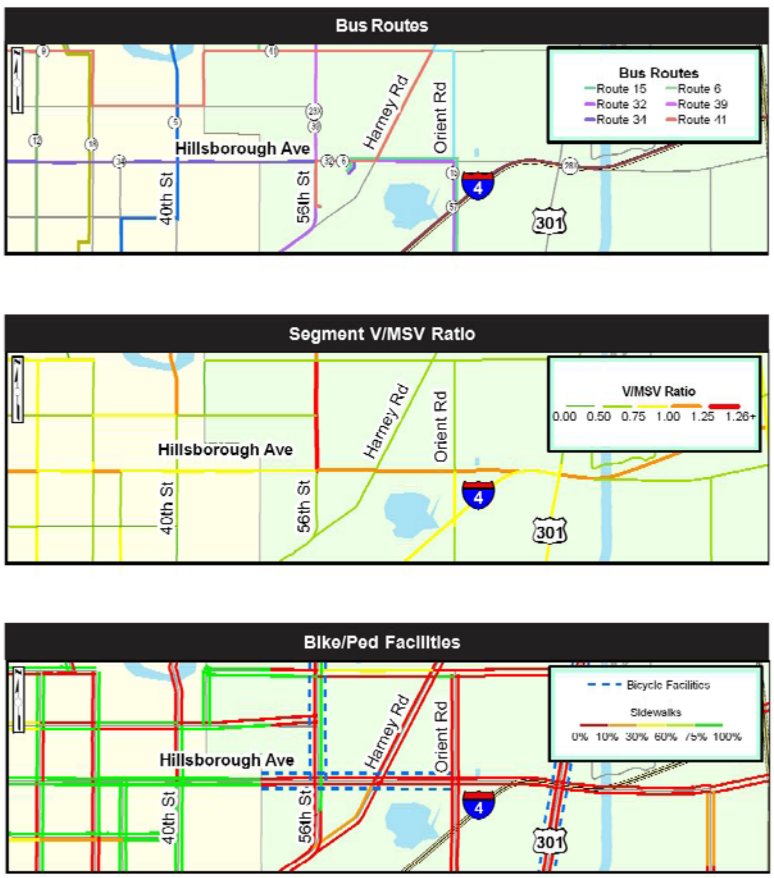
Corridor or sub-area studies provide opportunities for more focused and detailed consideration of sustainability measures and strategies. At the corridor level, accessibility performance measures become more specific, and the consideration of multimodal options can be refined. Agencies can measure improvements in bus headways, route ridership, signalization, and access management techniques. Analysis to compare potential solutions is often more time consuming and costly due to the level of detail required. However, this level of detail allows agencies to identify specific needs and to calibrate solutions to address them.

Multimodal analysis at the corridor or sub-area level can inform both the broader understanding of the regional transportation system as well as project-level decision-making. Another benefit to using corridor-level performance measures along with regional ones is the more efficient allocation of resources. For example, agencies can supplement volume or capacity information provided for the corridor by the travel demand model with transit ridership data and pedestrian and bicycle counts to identify where changes in mode split have occurred. This information informs the regional selection of individual strategies and provides specific data support for selecting project alternatives.

One example of this approach comes from the Hillsborough County MPO, covering the Tampa, Florida, area. The Hillsborough County MPO developed a tiered structure for performance measures that is intended to monitor the transportation system in an effective and resource-efficient way. The program measures performance by corridor, first applying Primary Performance Measures, including basic performance measures for roadway (volume-to-capacity), transit (ridership and frequency), bicycle (extent of corridor with bicycle facilities), and pedestrian travel (extent of corridor with sidewalks). For identified congested corridors, the MPO tracks a more detailed set of measures, drawing on data such as travel time surveys, pedestrian counts, employer rideshare programs, and transit on-time performance.

Figure 27 shows an example of how this information is presented for one corridor in the Congestion Management System Performance Report (Hillsborough Avenue).[41] Similar information is presented for all 39 corridors covered in the report.

Figure 27: Hillsborough County MPO (Tampa area) – Sample Corridor Performance Report



	2000	2004
Corridor Length (mi.)	2.50	2.51
Weighted V/MSV Ratio	1.25	1.10

Transit Service				
Route Number	Passengers/ Revenue Hour	Headway (minutes)		
		AM	Mid	PM
6	24.32	30	30	30
15	15.58	45	45	45
32	14.87	35-60	35-60	35-60
39	18.04	60	60	60
41	11.04	60	60	60

Sidewalk Availability	
% North Side	% South Side
29.3%	29.3%

Bicycle Facility Availability	
% North Side	% South Side
70.3%	70.3%

Programming

In the programming phase of decision-making, performance measures can be used to prioritize among candidate projects submitted for funding. Measures at this stage are often both qualitative (e.g., does the project support specific program objectives?) and quantitative (e.g., how much does the project reduce VMT or emissions?).

Many transportation agencies use performance measures to select projects to receive funding through the federal Congestion Mitigation Air Quality Program (CMAQ). For example, the Southwestern Pennsylvania Commission evaluates candidate projects using quantitative and qualitative measures. Using standardized tools from the Pennsylvania Department of Transportation, the commission estimates the following metrics for each project:

- Change in emissions.
- Change in VMT.
- Change in vehicle trips.
- Dollar per ton of emissions reduced by potential CMAQ activities.
- Dollar per unit change in vehicle trips and VMT from potential CMAQ activities.

The Southwestern Pennsylvania Commission also completes a scorecard to rate each candidate CMAQ project using qualitative measures. Based on federal guidance and regional priorities, the commission gives funding priority to the following types of eligible projects: diesel retrofits, traffic signal improvements, transportation demand management, and commuter bicycle/pedestrian improvements. They then score projects on nine ancillary selection factors, with each factor given a weight (5, 7, or 10) and assigned a score of low (1), medium (2), or high (3), as shown in Figure 28 (each project's scores are recorded in the blank columns).[42] These scorecards, together with the quantitative impact measures, result in a prioritized list of CMAQ projects.

Figure 28: Southwestern Pennsylvania Commission – CMAQ Project Rating Scorecard
Image source: ICF International

Factors	Weight	Score 1=low 2=med 3=high	Weighted Score	Best Possible Score
1. Consistency with 2035 Long Range Plan Vision and Policies that Impact Air Quality	10			30
2. CMP Congested Corridor Rating	10			30
3. Deliverability / Project Readiness	10			30
4. Raise Public Awareness of Transportation Demand Management Options	7			21
5. Grouped Projects	5			15
6. Safety Improvements	7			21
7. Sustainable Development Benefits	5			15
8. Projects that bring Non-Traditional Funding to TIP	5			15
9. Non-Federal Funding Share	5			15

MPOs can develop detailed measures to evaluate projects considered for inclusion in the TIP. In addition to traditional roadway projects, these evaluation measures can be extended to transit, bicycle/pedestrian, and other projects supportive of regional sustainability goals.

The Denver Regional Council of Governments (DRCOG) has developed eligibility requirements and evaluation criteria for 11 project types, including three types of transit projects, bicycle/pedestrian projects, and other enhancement projects.[43] For example, all bicycle/pedestrian projects must satisfy the following four eligibility requirements:

1) "Pedestrian and bicycle projects must be on facilities contained in an adopted local or regional plan.
2) Any new or reconstructed pavement must be designed and constructed to withstand occasional vehicle travel (emergency vehicles).
3) If project consists of multiple, non-contiguous elements, all elements must either be a) on the same facility (primary corridor) OR b) within ¼ mile of the largest element of the project.
4) Projects that consist of both a new construction element and an upgrade and/or reconstruction element must be categorized as either one or the other to score the project. That categorization is determined by the element proposed in the largest contiguous segment of the project, based on linear feet."

DRCOG then applies a detailed system for scoring candidate bicycle/pedestrian projects. Figure 29 shows the scoring system for new construction projects.[44] A separate set of measures is applied for scoring upgrade or reconstruction projects.

Figure 29: Denver Regional Council of Governments – TIP Evaluation Measures for Bicycle/Pedestrian Projects (New Construction)
Image source: ICF International

Evaluation Criteria	Points	Scoring Instructions
Safety	0 – 10	Projects will be evaluated on the anticipated *improvement* of existing safety problems to be made by building new facilities for non-motorized travel. Three measures of safety improvement will be awarded: **1. Relevant crash history** Based on the number of *documented* injury accidents: ▸ created by the interaction between motorized and non-motorized traffic; ▸ in the area to be affected by the proposed new facility; and ▸ occurring over the last three-year period for which data is available. 1 point will be awarded for each applicable injury accident, up to a maximum of 4. **2. Conflict factor** If the existing facilities are roadways that allow interaction between motorized and non-motorized traffic, and if the project will build new facilities for the non-motorized traffic, to eliminate or reduce the conflict factor, the project will earn safety points. Based on the speed limit on the existing facilities, up to 4 points will be awarded as follows: ▸ 1 points will be awarded if the existing speed limit is 30 MPH or less; ▸ 2 points will be awarded if the existing speed limit is 35 MPH; ▸ 3 points will be awarded if the existing speed limit is 40 MPH; or ▸ 4 points will be awarded if the existing speed limit is 45 MPH or above. **3. Facility lighting** 2 points will be awarded to projects that will provide ADA/AASHTO compliant lighting to facilitate non-motorized travel on the planned facilities, if no lighting is currently available.

Evaluation Criteria	Points	Scoring Instructions
Connectivity	0 - 17	Up to 17 points will be awarded for specific project attributes that address existing local or regional connectivity of non-motorized travel. Points will be awarded as follows: **Connectivity measures – gap closure** (score points for only one of these two) • 4 points - completely closing a gap between two existing bicycle facility/sidewalk sections. • 2 points - completely closing a gap between an existing pedestrian/bicycle facility and an RTP roadway that serves pedestrian/bicyclists. **Connectivity measures – access** (score points for only one of these three) • 3 points - provide direct access (project directly touching) to a school. • 2 points - provide direct access (project directly touching) to an employment center with greater than 2,000 jobs. • 1 points - provide direct access (project directly serving) to such destinations as employment, shopping, dining, or government buildings, or recreational destinations such as parks or recreational facilities. **Connectivity measures – barrier elimination** (score points for only one of these three) • 5 points - entirely eliminate a barrier (railway, highway, waterway) for pedestrians or cyclists by grade separating. • 3 points - entirely eliminate a barrier (railway, highway) for pedestrians or cyclists by providing a controlled crossing where one does not currently exist (demonstrate achievement of signal warrant if signal proposed). • 1 point - construct at least one phase of a multi-phase improvement (as dictated through an approved plan) towards eliminating a barrier (railway, highway, waterway). **Connectivity measures – transit** (score points for only one of these if applicable) • 3 points - provide new direct access to "transit" within 1.5 miles for bike projects and within 0.5 miles for pedestrian projects. "Transit" is stations, park-n-Ride lots, or transit terminals existing, in final design, or under construction; or existing bus stops serving 3 or more routes. • 1 point - provide new indirect access (serving via an existing linkage) to "transit" within 1.5 miles for bike projects and within 0.5 miles for pedestrian projects. "Transit" is stations, park-n-Ride lots, or transit terminals existing, in final design, or under construction; or existing bus stops serving 3 or more routes. **Connectivity measures – location** (score 2 points maximum) • 2 points – project is located in the jurisdiction of more than one local governmental entity (with written confirmation and agreement by the other affected governmental entities besides the applicant). • 1 point – project connects 2 or more neighborhoods where an exclusive bicycle and/or pedestrian access does not currently exist, excluding roadways.
Multiple Enhancements	0 – 4	Up to 4 points will be awarded for multiple enhancements (score all that apply): • 2 points if project will provide facilities for bidirectional use by both bicycles and pedestrians (10 ft. minimum width) • 1 or 2 points if project will provide bicycle lockers or racks; 1 point for each 10 racks or 3 lockers, up to 2 points
Air Quality Benefits	0 – 8	New bike/ped projects may reduce air pollution by reducing VMT. Based on the daily reduction in pounds of total air pollutants expected from this project, as a percentage of the regional total from mobile sources, 8 points will be awarded to projects which would reduce 0.3% of the regional total or more; 0 points to projects which would reduce no pollution; with straight-line interpolation between.

Performance Monitoring

Performance monitoring enables a region to observe trends in key indicators and assess the progress the region is making toward its goals and objectives. Many MPOs create an annual "state of the region" report that showcases selected performance measures in areas such as transportation, land use, environment, economic development, and public health. A long-range transportation plan can also identify performance-monitoring measures that relate directly to the plan goals and objectives.

The Mid-America Regional Council identified one or more performance measures to assess progress toward each of the nine goals adopted as part of the region's 2040 plan, shown in Figure 30.[45] The measures and associated data are intended to "inform decisions and strategies that will be necessary to move these indicators in the desired direction toward stated goals."

Figure 30: Mid-America Regional Council – Performance Measures in the Transportation Outlook 2040 Plan

Image source: ICF International

Goal	Factor	Measure
Accessibility	Level of Transit Service	Revenue service hours Ridership
	Environmental Justice	Percent of transportation investments in environmental justice tracts
Economic Vitality	Transportation Costs	Combined transportation and housing costs as a percentage of median income
Climate Change/ Energy Use	Vehicle Miles Traveled /CO_2	Systemwide daily VMT/CO_2 emissions
	Vehicle Occupancy	Vehicle occupancy rate
Environment	MetroGreen Network	Percent/miles of MetroGreen Network Completed
Place Making	Multi-modal Options	Modal balance (mode share)
Public Health	Ozone	Ozone levels
	Physical Health	Obesity rate
Safety and Security	Crash Fatality and Injury Rate	Annual crash fatalities and disabling injuries
System Condition	Bridge & Pavement Condition	Pavement condition Bridge condition
System Performance	Level of Service	Observed speed vs. posted speed on Congestion Management System network
	Congestion	Percent of Congestion Management System network congested
	Travel Time	Average commute time
	On-Time Performance	On-time performance of transit system

Conclusion

The examples described in this guidebook indicate the growing interest in both performance-based planning and in making transportation environmentally and economically sustainable over the long term. By providing sample performance measures, identifying where in the transportation decision-making process they can be applied, and offering examples of recent transportation agency work in this area, this guidebook can spur further interest and innovation.

Developing and using performance measures is not necessarily easy. At a minimum, it requires working with stakeholders to identify the most appropriate measures and new analysis and reporting by MPO staff. In some cases, it requires collecting new data or assembling and processing data collected by other agencies, both of which can be time consuming and costly. Perhaps the biggest challenge is overcoming resistance to changing long-established procedures for prioritizing projects.

Nonetheless, the rewards of these efforts can be substantial. MPOs have found that, once they begin to report performance measures, stakeholders quickly see their value and then come to expect regular reporting of measures and a more explicit linkage between the measures and public agency decisions. Transportation agency staff and stakeholders can then engage in a much richer conversation about the trade-offs among policy and investment decisions and the best opportunities for a region or state to reach its sustainability goals.

Endnotes

1 Transportation Research Board Sustainable Transportation Indicators Subcommittee. Sustainable Transportation Indicators: A Recommended Research Program for Developing Sustainable Transportation Indicators and Data. 2008. http://www.vtpi.org/sustain/sti.pdf

(Note: The definition endorsed by the Subcommittee originally came from the European Council of Ministers of Transport.)

2 U.S. Environmental Protection Agency. HUD-DOT-EPA Partnership for Sustainable Communities. http://www.epa.gov/smartgrowth/partnership/index.html

3 Puget Sound Regional Council. Transportation 2040: Draft Environmental Impact Statement. 2009. http://www.psrc.org/transportation/t2040/t2040-pubs/trans2040-deis/

4 Delaware Valley Regional Planning Commission. Tracking Progress Toward 2030: Regional Indicators for the DVRPC Long Range Plan. http://www.dvrpc.org/LongRangePlan/RegionalIndicators/

5 Atlanta Regional Council. 2030 Regional Transportation Plan. http://www.atlantaregional.com/transportation/regional-transportation-plan

6 San Diego Association of Governments. 2030 Regional Transportation Plan. http://www.sandag.org/index.asp?projectid=292&fuseaction=projects.detail

7 Puget Sound Regional Council. Transportation 2040: Draft Environmental Impact Statement. 2009. http://www.psrc.org/transportation/t2040/t2040-pubs/trans2040-deis/

8 Metropolitan Transportation Commission. Transportation 2035 Plan for the San Francisco Bay Area, Performance Assessment Report. 2008. http://www.mtc.ca.gov/planning/2035_plan/Supplementary/T2035Plan-Perf_AssessmentReport.pdf

9 Endnote deleted.

10 California Environmental Protection Agency, Air Resources Board. EMFAC2007 Release. http://www.arb.ca.gov/msei/onroad/latest_version.htm

11 U.S. Department of Energy, Energy Efficiency and Renewable Energy. Electric Vehicles. http://www.fueleconomy.gov/feg/evtech.shtml

12 Metropolitan Transportation Commission. Transportation 2035 Plan for the San Francisco Bay Area, Performance Assessment Report. 2008. http://www.mtc.ca.gov/planning/2035_plan/Supplementary/T2035Plan-Perf_AssessmentReport.pdf

13 Kockelman, Kara. “Travel Behavior as Function of Accessibility, Land Use Mixing, and Land Use Balance: Evidence from San Francisco Bay Area.” Transportation Research Record: Journal of the Transportation Research Board. 1997. No. 1607.

14 Sacramento Area Council of Governments. Preferred Blueprint Alternative. http://www.sacregionblueprint.org/

15 Metropolitan Transportation Commission. Transportation 2035 Plan for the San Francisco Bay Area, Performance Assessment Report. 2008. http://www.mtc.ca.gov/planning/2035_plan/Supplementary/T2035Plan-Perf_AssessmentReport.pdf

16 U.S. Environmental Protection Agency. Environmental Justice Basic Information. http://www.epa.gov/compliance/ej/basics/index.html

17 U.S. Department of Transportation, Federal Highway Administration. Title VI – Nondiscrimination in Federally Assisted Programs. http://www.fhwa.dot.gov/environment/title_vi.htm

18 Puget Sound Regional Council. Transportation 2040: Draft Environmental Impact Statement. 2009. http://www.psrc.org/transportation/t2040/t2040-pubs/trans2040-deis/

19 Southern California Association of Governments. 2008 Regional Transportation Plan: Making the Connections, Environmental Justice Report. http://www.scag.ca.gov/rtp2008/index.htm

20 Puget Sound Regional Council. Transportation 2040: Draft Environmental Impact Statement. 2009. http://www.psrc.org/transportation/t2040/t2040-pubs/trans2040-deis/

21 Mid-Ohio Regional Planning Commission. Regional Fact Book. 2004. http://www.morpc.org/pdf/RegionalFactBook.pdf

22 National Bicycle and Pedestrian Documentation Project. http://bikepeddocumentation.org

23 City of Portland, Oregon. Portland Bicycle Count Report. 2009. http://bikeportland.org/wp-content/uploads/2010/01/bikecount2009reportfinal.pdf

24 City of Portland, Oregon. Portland Bicycle Count Report. 2009. http://bikeportland.org/wp-content/uploads/2010/01/bikecount2009reportfinal.pdf

25 Chicago Department of Transportation. City of Chicago Traffic Information. http://www.cityofchicago.org/traffic/

26 Transportation Research Board. Highway Capacity Manual 2010. http://www.trb.org/Main/Blurbs/Highway_Capacity_Manual_2010_HCM2010_164718.aspx

27 Transportation Research Board, National Cooperative Highway Research Program. Report 616: Multimodal Level of Service Analysis for Urban Streets. 2008. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_616.pdf

28 Florida Department of Transportation. Quality/Level of Service Handbook. 2009. http://www.dot.state.fl.us/planning/systems/sm/los/pdfs/2009FDOTQLOS_Handbook.pdf

29 Transportation Research Board. Highway Capacity Manual 2010. http://www.trb.org/Main/Blurbs/Highway_Capacity_Manual_2010_HCM2010_164718.aspx

30 Chicago Area Transportation Study. Soles and Spokes: The Pedestrian and Bicycle Plan for Chicago Area Transportation. 2004. http://www.catsmpo.com/prog-bikeped.htm

31 U.S. Environmental Protection Agency. Transportation-Related Documents – Commuter Programs. http://www.epa.gov/oms/stateresources/policy/pag_transp.htm#cp

32 University of South Florida Center for Urban Transportation Research. http://www.cutr.usf.edu/index.shtml

33 Mid-America Regional Council. Transportation Outlook 2040. 2010. http://www.marc.org/2040/

34 U.S. Department of Transportation, Federal Transit Administration. Public Transportation's Role in Responding to Climate Change. 2010. http://www.fta.dot.gov/documents/PublicTransportationsRoleInRespondingToClimateChange2010.pdf

35 Portland Metro. Draft 2035 Regional Transportation Plan. 2010. http://www.oregonmetro.gov/index.cfm/go/by.web/id=25036

36 Mid-America Regional Council. Transportation Outlook 2040. 2010. http://www.marc.org/2040/

37 Portland Metro. Draft 2035 Regional Transportation Plan. 2010. http://www.oregonmetro.gov/index.cfm/go/by.web/id=25036

38 Metropolitan Transportation Commission. Transportation 2035 Plan for the San Francisco Bay Area, Performance Assessment Report. 2008. http://www.mtc.ca.gov/planning/2035_plan/Supplementary/T2035Plan-Perf_AssessmentReport.pdf

[39] Metropolitan Transportation Commission. Transportation 2035 Plan for the San Francisco Bay Area, Performance Assessment Report. 2008. http://www.mtc.ca.gov/planning/2035_plan/Supplementary/T2035Plan-Perf_AssessmentReport.pdf

[40] Central Lane Metropolitan Planning Organization. Regional Transportation Plan. 2007. http://docs.lcog.org/mpo/PDF/rtp/2031/2031RTP_Chapters1-4_Nov-07Adoption_Corrected.pdf

[41] Hillsborough County Metropolitan Planning Organization. Congestion Management System Performance Report. 2005. http://www.hillsboroughmpo.org/pubmaps/pubmaps_folders/congestion-management-process-its-plan/March%202006%20RCMS.pdf/view

[42] Southwestern Pennsylvania Commission. Application Instructions: Congestion Mitigation Air Quality Program for the 2011-2014 Transportation Improvement Program. 2009. http://www.spcregion.org/pdf/cmaq09/SPC_CMAQ_InstructionPackage_2009.pdf

[43] Denver Regional Council of Governments. Policy on Transportation Improvement Program Preparation, Procedures for preparing the 2008-2013 TIP. 2007. http://www.drcog.org/documents/2008-2013%20TIP%20Policy%20FINAL%20Amended%2012-19-07.pdf

[44] Denver Regional Council of Governments. Policy on Transportation Improvement Program Preparation, Procedures for preparing the 2008-2013 TIP. 2007. http://www.drcog.org/documents/2008-2013%20TIP%20Policy%20FINAL%20Amended%2012-19-07.pdf

[45] Mid-America Regional Council. Transportation Outlook 2040. 2010. http://www.marc.org/2040/