**Title**

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**Publication Date**

2010

Peer reviewed

SafeTREC Safe Transportation Research & Education Center

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2010
RR-2010-3
http://www.safetrec.berkeley.edu

# Performance Measures for Complete, Green Streets: A Proposal for Urban Arterials in California

**Abstract**

The California Department of Transportation (Caltrans or "Department") manages more than 15,000 miles of state highways, ranging in scale and function from local streets to interstate highways. Historically, Caltrans has been governed by the principles of highway engineering, which focus on providing mobility to motorized vehicles. Over the past decade, however, the Department has joined in a national movement to better incorporate non-motorized transportation and community-level outcomes into its transportation decision-making framework, embodied by the approach known as "Complete Streets." Recognizing that Caltrans' current performance measurement system does not reflect this shift toward Complete Streets principles, researchers at the University of California, Berkeley created new measures to more accurately gauge Departmental progress toward these objectives. This paper elaborates on a proposed framework of performance measures for encouraging non-motorized transportation and increasing the environmental sustainability of the transportation system. The framework focuses on urban arterials, which carry high amounts of multimodal traffic and constitute 26% of California's urban roadway network. Based on Complete Streets principles and the findings from an extensive literature review, the proposed framework compliments Caltrans' current performance measurement system and presents an opportunity for the Department to become a national leader in encouraging non-motorized transportation and preserving the environment.

## 1. INTRODUCTION

Communities throughout California and around the United States are rethinking street design in their downtowns and around their neighborhoods. Citing the adverse effects of high volumes of motorized traffic moving much faster than pedestrians and bicyclists (e.g., decreased roadway safety, walkability, and bikability, and increased air and water pollution levels due to vehicle emissions), many communities desire transportation corridors that are designed to meet local needs as well as throughput needs, and that safely accommodate multiple travel modes. Although efforts to enhance the quality of life within communities are supported by an increasing focus among city planners, designers, transportation engineers, and public health practitioners, professionals lack a framework to comprehensively measure progress toward this broad objective. Recognizing this gap within the measurement system used by the California Department of Transportation, and inspired by the Department's Landscape Architecture Division, researchers at the University of California, Berkeley initiated this research project to provide such a framework.

State departments of transportation routinely use performance measures to assess their transportation systems, but assessment is generally based in the traditional highway engineering perspective of providing for automobiles, or is limited to monitoring whether departmental goals are achieved cost effectively or generate quantifiable net benefits. Although corridor design elements that support livable and sustainable communities have been identified through research, few defensible performance measures exist for assessing their effects on user safety, multimodal mobility, and environmental quality; certainly, no comprehensive framework of such measures presently exists. This paper reports on a research project aimed to create such a framework, based upon defensible research findings and best practices. The framework was created specifically for urban arterials, which constitute 26% of the urban roadway network in California and carry high amounts of local traffic, particularly pedestrians and bicyclists, due to their density of attractions such as businesses, restaurants, and stores. Although it is intended for use by Caltrans and other state DOTs, the framework is adaptable to all arterial roadways, and usable by local agencies aspiring to create multimodal, sustainable streets.

The framework is strongly influenced by the principles of the national Complete Streets movement, which urge that transportation facilities be "planned, designed, operated, and maintained to provide safe mobility for all users, including bicyclists, pedestrians, transit riders, and motorists appropriate to the function and context of the facility" *(1)*. In addition, the framework was shaped by the Green Streets movement, which advocates for sustainable street design. Specifically, Green Streets maximize permeable surfaces, tree canopy, and landscaping elements in order to divert stormwater from the sewer system, reduce the amount of polluted stormwater entering rivers and streams, reduce impervious surfaces so stormwater can recharge the natural water supply, and increase urban green space *(2)*.

The UC Berkeley project was conducted in two phases. Phase I involved a broad literature review of research on transportation corridor roadside design features and their effects on user safety and behavior, health, community and economic vitality, and the environment. Phase II included a review of performance measures in theory and practice, a review of policies and plans that guide Caltrans' project selection and design, and the development of the proposed *Complete, Green Streets Performance Measures Framework.* Although this paper concentrates on the proposed framework, select findings from the literature review are presented before the relevant proposed objectives in Section 3. The complete literature review is available at http://repositories.cdlib.org/uctc/878_fall_2008. Additional information on the development and use of performance measures can be found in the complete report, *Performance Measures for Complete, Green Streets: A Proposal for Urban Arterials in California* (publication pending, 2009). A separate project to field-test the proposed performance measures began July 1, 2009.

## 2. SUPPORTING POLICIES, PLANS, AND LEGISLATION

This section briefly describes one key element of this multi-year project: the examination of the many layers of policy, planning, and legislation affecting Caltrans. The review found a growing body of adopted material, ranging from State Senate Bill 375 (*Regional Planning for Greenhouse Gas Reduction*) to Caltrans' Strategic Plan, which indicate the State's intention and responsibility to address environmental issues, as well as pedestrian and bicyclist safety and mobility, through more community-serving transportation facility design. There has been a particular focus on Complete Streets principles, building upon federal and state policies that promote the development of multimodal, community-serving streets – notably the 2007 California Complete Streets legislation that requires a city or county to identify how it provides for the routine accommodation of all roadway users, including motorists, pedestrians, bicyclists, individuals with disabilities, seniors, and transit riders, when the circulation element of a general plan is updated *(3)*. In addition, Caltrans' Deputy Directive 64-R1 Complete Streets (2008) recognizes "bicycle, pedestrian, and transit modes as integral elements of the transportation system," and that Caltrans "provides for the needs of (all) travelers…in (all) planning, programming, design, construction, operations, and maintenance activities and products on the State highway system" *(1)*. This political and professional momentum heavily influenced the development of the proposed framework.

## 3. PROPOSED FRAMEWORK

### 3.1 Caltrans' Current Use of Performance Measures

To monitor the state's transportation system, Caltrans currently uses performance measures based on five high-level goals related to safety, mobility, delivery, stewardship, and service *(4)*. Each goal is accompanied by objectives that have numerical targets and timeframes coordinated with the Strategic Plan that Caltrans adopts every five years *(4)*. At the end of each fiscal year, performance is measured and compared with the results of previous years, allowing Caltrans to gauge overall progress toward objectives. Caltrans' current measurement system focuses on motorized travel: it contains no objectives or measures concerned with the safety and mobility of non-motorized travelers, and none concerned with environmental quality, other than litter clean-up. Clearly, momentum exists within Caltrans for taking a more holistic approach to building the transportation system; however, this vision has not been comprehensively adopted.

The proposed *Complete, Green Streets Performance Measure Framework* fills the gap for pedestrian and bicycle safety and mobility, as well as environmental stewardship. (Transit, though an essential element of a Complete Street, is excluded from this proposal because the literature review did not address it.) By combining the new framework with its existing measures, the Department would take a major step toward creating a meaningful and comprehensive system to measure progress toward a multimodal and community-serving transportation network.

To facilitate incorporation of the new objectives and measures, the proposed framework is presented using Caltrans' existing structure and format. Each section begins with the Department's adopted goals followed by a review of the relevant research findings from the literature review. The proposed objectives and performance measures, labeled "CGS objectives" (for Complete, Green Streets), and "PM", respectively, are then listed and followed by a discussion of their development. In several places, an "X" is used as a placeholder for a year or target where more work is needed before a finite target year or level (i.e., reduce injury rate to 1 per 1 million vehicle miles traveled) could be set. It is recommended that Caltrans apply the same target-setting methodology for these new measures that it uses for its existing performance measures, incorporating stakeholder involvement when necessary.

## 3.2 Proposed Complete, Green Streets Objectives and Measures

### SAFETY

The Literature Review revealed the following findings regarding street design and safety: narrowing lane widths has been associated with slower driving speeds *(5-6)* and collision rates that were generally reduced or unchanged *(7)*; higher driving speeds were found to be more associated with vehicle crashes and fatalities than slower speeds *(8)*. In addition, street sections with landscaping and amenities, where low speed is communicated through design, are often found to have fewer vehicular collisions and fewer pedestrian and bicyclist injuries and fatalities *(9-10)*. Higher speeds make it more difficult for motorists to slow down in time to avoid a collision *(11)*, and they make it more likely that pedestrians will suffer serious injuries if they are hit: pedestrians sustain serious injuries when hit by a car going just 25 mph; fatal injuries can occur at 35 mph *(12)*. In addition, fast driving speeds are associated with low perceptions of safety for pedestrians and cyclists.

Research has shown that most severe and fatal crashes involving pedestrians occur on arterial and collector streets, due to their higher travel speeds *(13)*. Fortunately, pedestrian crosswalk installation has been generally positively associated with increased usage by pedestrians and slightly decreased driver speed approaching the intersection, particularly if ancillary traffic safety treatments are installed *(14-16)*. However, drivers may misunderstand the laws governing crosswalks, leaving pedestrians vulnerable when crossing the street, particularly on multi-lane roadways. Therefore, marked crosswalks at unsignalized locations should be installed with supplementary measures such as flashing lights or red beacons on all multi-lane roadways and in areas with high volumes of or fast-moving traffic *(17-19)*. In-pavement lighting is one such measure that has been found to be highly successful in encouraging driver yielding and pedestrian crosswalk compliance, particularly in areas of moderate to intense pedestrian traffic *(20-23)*.

Pedestrian countdown signals have been positively associated with increased pedestrian compliance with signalization, leading to safer crossing behavior *(24)*. In addition, leading pedestrian intervals have been associated with reduced crash rates at intersections allowing right turns on red *(25)*. Finally, the principle of "safety in numbers" suggests that higher numbers of pedestrians lead to increased driver awareness and safer driving *(26)*.

These research findings urge special consideration for non-motorized safety on urban arterials.

***Caltrans' Safety Goal: Provide the safest transportation system in the nation for users and workers.***

Proposed CGS Objective 1.1: *By 2012, reduce the annual pedestrian and bicycle injury and fatality rates to the following levels, and continuously reduce annually thereafter with the goal of having the lowest rates in the nation.*

*Targets:*

- *Pedestrian fatality rate: X per X walking trips.*
- *Pedestrian injury rate: X per X walking trips.*
- *Bicyclist fatality rate: X per X bicycle trips.*
- *Bicyclist injury rate: X per X bicycle trips.*

*PM 1.1a: Rate of pedestrian fatalities per walking trips.*
*PM 1.1b: Rate of pedestrian injuries per walking trips.*
*PM 1.1c: Rate of bicyclist fatalities per bicycling trips.*
*PM 1.1d: Rate of bicyclist fatalities per bicycling trips.*

In existing performance measures, Caltrans tracks the safety of workers and drivers, but not specifically of non-motorized users. The current measure for traveler safety is fatalities per 100 million VMT, which ostensibly accounts for non-motorized travelers, but obscures trends in pedestrian and bicyclist fatalities, as these modes travel far fewer miles each year. Although Caltrans' Strategic Highway Safety Plan attempted to redress this lack, it measures overall amounts, rather than rates of injuries and fatalities, thus ignoring the impact of exposure on the true picture of pedestrian and bicycle safety on Caltrans roadways. In addition, urban arterials must be measured separately from other state highways, as measuring all state highways together would obscure the difference in non-motorized usage between road types.

To truly meet its goal of providing a safe system for all users, Caltrans should adopt a broad, system-wide approach to improving pedestrian and bicyclist safety along urban arterials. Because only some of the transportation facilities in an urban area are state-owned and operated, this safety objective will require Caltrans to coordinate with other jurisdictions and stakeholders who are involved in planning, operating, and using the local transportation system. A comprehensive approach that incorporates facility improvements, safety programs, and educational campaigns may be required.

Some challenges to measuring the rate of pedestrian and bicyclist injury and fatality should be noted. First, there is limited data on the number of pedestrian and bicyclist trips occurring on state urban arterials. While Caltrans works to generate better data on the number of non-motorized trips, statewide mode share data from the Census can be used as a proxy for walking and biking trips on urban arterials; however, due to well-known issues with using Census data, this is not the ideal dataset. In addition, current data does not differentiate between road types when reporting injuries and fatalities.

Second, injury and fatality rates can be misleading in cases where there are no deaths or injuries because no one is walking or biking in a certain location. For this reason, overall trips (measured in proposed CGS Objective 2.1) must also be measured and considered in relation to injury and fatality rates. Third, pedestrian and bicyclist injuries and fatality records often under-represent the actual number of incidents. Police records do not always accurately record the type of collision, and anecdotal evidence suggests that many crashes go unreported. Furthermore, injury and death data from hospitals is rarely cross-referenced with police report data. For these reasons, the rates calculated for this measure should be used primarily to monitor trends, and

Caltrans should work with partner agencies to improve the collection of injury and fatality data for pedestrians and bicyclists.

Proposed CGS Objective 1.2: *By 2017, double the percentage of Californians who feel safe using non-motorized modes on urban arterials. By 2022, increase this percentage to XX%.*

*PM 1.2: Percentage of Californians who feel safe using non-motorized modes on urban arterials.*

Because they play an important role in the decision to walk or ride a bicycle, non-motorized users' perceptions of safety must also be measured. Monitoring user attitudes will help gauge perceived safety among all system users, not just those who currently choose to walk or bike. Measure 1.2 will help the Department direct resources to areas that might yield the greatest improvements in perceived safety and use.

Caltrans should begin measuring perceived safety through its annual External Customer Survey, which includes a user survey. The survey could be administered to all state residents by mail, as done in Oregon. With enough responses, the rate can be determined using the number of positive responses over the total number of responses, which will serve as a statistically significant proxy for population. The proposed timeline suggests that Caltrans administer the first user survey in 2012 in order to set a baseline for the number of system users who feel safe walking and biking on Caltrans urban arterials.

Proposed CGS Objective 1.3: *By 2012, all Caltrans urban arterial projects (new expenditures) are designed to increase safety for non-motorized users in accordance with Complete Streets principles. By 20XX, all Caltrans urban arterials are designed for safety according to these principles.*

*PM 1.3a: Percent of signalized intersections along urban arterials with marked crosswalks and one or more of the following: countdown signals, leading pedestrian intervals, bulb-outs, or pedestrian refuge islands.*
*PM 1.3b: Percent of unsignalized 4-way (multilane) intersections along urban arterials with marked crosswalks and one or more of the following: HAWK signal*, yield to pedestrian signage, user-activated overhead warning lights.*
*PM 1.3c: Percent of urban arterial intersections with one or more of the following improvements geared toward bicyclists: bike box*, painted bicycle lane through the intersection*, bicycle signal, bicycle detectors, bicycle left turn lane.*
*PM 1.3d: Percent of urban arterials on which the 85th percentile driving speed is no greater than 25 mph.*

*The HAWK signal has not yet been approved for use in California, although it or similar beacons are expected to be so in the future. Bicycle boxes and painted bicycle lanes have been approved for provisional use.

To build Complete Streets, Caltrans must incorporate pedestrian and bicycle safety treatments into all of its urban arterial projects. Performance measures 1.3 a, b, and c compliment CGS Objectives 1.1 and 1.2 by measuring the percent of urban arterial intersections in the Caltrans system with specified treatments geared toward pedestrian and bicyclist safety (countdown signals, HAWK signals, bicycle detectors, etc.). Measures 1.3a and b focus on improving pedestrian safety, while measure 1.3c focuses on enhancing bicycle safety.

Note: These measures are not meant to prescribe design treatments for urban arterial intersections or to result in all treatments being used at all locations. Instead, performance measures 1.3 a, b, and c provide designers with a list of approved* treatments that have a demonstrated effect on motorist, pedestrian, and/or bicycle behavior and safety, with the goal of a system-wide increase in the application of these treatments. Designers should use their professional judgment to create context-sensitive solutions for each intersection. With regard to treatments that have not been widely applied in California, close consultation with design guidelines and/or pedestrian and bicycle professionals may be necessary.

Although intersections are the most common place of conflict, road sections must also be designed to promote the safety of travelers. Performance Measure 1.3d is intended to address design speed. Historically, Caltrans' mission of "improv(ing) mobility in California" has meant increasing driving speeds; however, this can be highly detrimental to traveler and community safety, especially in urban areas. In order to build Complete Streets, Caltrans must apply a balanced approach that provides multimodal mobility without sacrificing the safety of any users.

In California, jurisdictions can petition to change speed if 85% of drivers are shown to be driving a certain speed. In other words, the 85$^{th}$ percentile rule adjusts the law (speed limit) to fit the behavior (actual speed). While this system may be appropriate on freeways and major highways, it is not suited to urban environments where roads are shared by a variety of users – many of whom are going much slower than 85% of the motorized traffic. In addition, research has shown that posted speed limit signs have a limited effect on reducing driving speeds when not accompanied by enforcement and roadway design *(27)*. While enforcement can be effective, it is a reactive approach that is limited by financial resources. The most proactive and long-term approach is to design arterials for the safest and most appropriate speed for each location.

There is a range of design treatments that can help accomplish desired vehicle speeds and increase user safety while maintaining system throughput. Since the most effective and feasible design treatment for achieving target speeds will vary among projects, Performance Measure 1.3d maintains a high level of professional discretion for Caltrans designers by measuring an output (driver speed) rather than any particular physical or operational feature of the roadway. In some conditions, speed-calming measures like center islands may be appropriate. Lane narrowing from 12 to 10 feet may also be a desirable approach, especially on urban arterials and in places with limited right-of-way. According to the AASHTO *Green Book*, "narrower lane widths are normally quite adequate and have some advantages" on signalized arterials operating at less than 45 MPH (all urban arterials). Furthermore, vehicle capacity has been shown to be minimally or not at all affected by a reduction of lane widths from 12 to 10 feet *(Zegeer, John. Memo to Sprinkle Consulting Engineers, March 22, 2007. Unpublished data).*

Proposed CGS Objective 1.4: *By 2012, annually reduce the number of pedestrian and bicycle hotspots (high concentration of collisions) on urban arterials.*

*PM 1.4a: Overall number of pedestrian collision hotspots on urban arterials.*
*PM 1.4b: Overall number of bicycle collision hotspots on urban arterials.*

Caltrans must also work specifically to address its most unsafe locations. The Department already has a process for mapping and responding to vehicle collision hot spots, functionally defined as any cluster of collisions. This performance measure extends that process to bicycle- and pedestrian-specific collision clusters. Because pedestrian, bicyclist, and driver safety each depend on a different set of roadway characteristics, it is essential that each mode be analyzed individually. Since this performance measure applies only to urban arterials, hot spots should be analyzed against collisions occurring on similar road types, as is currently done for automobiles.

## MOBILITY

Research from the Literature Review found that walkability is influenced by the connectivity of streets, provision of sidewalks, and design of the neighborhoods and roadways as well as by a mix of land uses *(28-32)*. The literature also suggested that those who live in highly walkable neighborhoods walk more than those who live in areas of low walkability, even controlling for self-selection *(33-34)*. Related literature suggested that people are willing to walk farther than commonly assumed (one-half versus one-quarter mile) for utilitarian purposes *(35)*, but that pedestrians were more sensitive to delay than those driving or taking transit *(36)*.

Research on pedestrian level of service (LOS) at signalized intersections indicated that conflicts with turning vehicles, as well as the volume and speed of perpendicular traffic, have the most negative effect on pedestrians' perceptions of comfort *(37)*. Pedestrian LOS for mid-block crossings was found to increase as the width of painted or raised medians increased, and when a crosswalk and/or pedestrian signals were present *(38)*; these may mitigate the "barrier effect" of high volumes of traffic *(39-40)*.

Bicyclists also tend to be discouraged by high volumes of traffic *(39-40)*, are sensitive to delay *(36),* and are "safe(r) in numbers" *(26)* - as can be seen in the statistics from Portland's years of bicycle counts and crash data from bridge crossings *(41)*. Although little research exists on new types of bicycle facilities and safety or usage, research on bicycle lanes has revealed a major opportunity to improve bicyclists' comfort. Several surveys have documented a strong stated preference for more bicycle lanes and trails *(42-44)*. Other studies reveal a clear willingness to travel longer to get to a bicycle lane and avoid riding in mixed traffic *(45-47)*. High amounts of auto traffic were positively associated with increased perceptions of cycling risk, which can be helped by the presence of bicycle lanes *(48)*. Research on bicycle LOS found that the presence or absence of a bicycle lane was the most commonly cited reason for scoring a roadway high or low, respectively *(49)*.

Revealed preferences also show a connection between bicycle facilities and cycling activity. In cities with populations over 250,000, each additional lane of Class II bicycle lanes per square mile was found to be associated with approximately one point increase in the percentage of bicycle commuters *(50)*. The presence of bicycle lanes and paths is positively associated with the amount of bicycling through a neighborhood *(29)*, and each additional mile of bicycle lane in a city was positively associated with a 5% increase in the likelihood of people to own a bicycle and to have ridden it in the week prior to the survey *(51)*. An analysis of comprehensive investment in bicycling facilities in Portland, Oregon, found that a 215% increase in the bicycle network was matched by a doubling of the overall bicycle commute share, and a

210% increase in the number of bicycle trips in the surrounding areas *(52)*. Another Portland study found that cyclists riding for utilitarian purposes rode mainly on facilities with bicycle infrastructure, nearly 30% of travel occurred on streets with bicycle lanes, and that bicyclists often go out of their way to use bicycle facilities, even when it lengthens trip time *(53)*.

In addition to facility provision, network connectivity is important. A highly connected bicycle network leading to desirable destinations has been found to be positively associated with the number of bicyclists in a city *(42, 52, 54)*. When bicycle lanes can't be provided, alternatives, such as shared lane markings, or "sharrows", can help complete the network. Sharrows have also been found to encourage safer bicycling behavior on roadways where bicyclists and automobiles share lanes *(55)*.

### *Caltrans' Mobility Goal: Maximize transportation system performance and accessibility.*

Proposed CGS Objective 2.1: *By 2012, all Caltrans urban arterial projects (new expenditures) are designed to increase mobility for non-motorized users in accordance with Complete Streets principles, aiming to link up to a larger community bicycle and pedestrian network where possible. By 20XX, all Caltrans urban arterials are designed for non-motorized mobility according to these principles.*

*PM 2.1a: On urban arterials, ratio of sidewalk mileage to centerline roadway mileage, bidirectionally.*
*PM 2.1b: On urban arterials, ratio of Class II bicycle facility mileage to centerline roadway mileage, bidirectionally.*
*PM 2.1c: On urban arterials, percentage of intersections that are ADA compliant.*
*PM 2.1d: Percentage of urban arterial projects designed as Complete Streets.*
*PM 2.1e: Number of pedestrian trips on urban arterials.*
*PM 2.1f: Number of bicycle trips on urban arterials.*

To accomplish its Complete Streets directive, Caltrans must begin measuring the mobility of *travelers*, not automobiles. Mobility is the ability and efficiency, usually measured in time, with which one can move between places. However, the mobility of pedestrians and bicyclists is different than that for automobiles. For bicyclists and pedestrians, the first measure of mobility is whether a reasonable travelway *exists* for walking or biking. For this reason, proposed mobility performance measures 2.1a and b gauge the system-wide presence of sidewalk and Class II bicycle facilities, respectively, in comparison to roadway miles. Improving broader system connectivity is critical to enhancing mobility. To accomplish this, Caltrans should work with local jurisdictions to consider how bicycle and pedestrian facilities on urban arterials connect to surrounding streets and reflect local bicycle and pedestrian plans where possible.

The Department must also measure the accessibility of facilities to people with disabilities. The Americans with Disabilities Act (ADA) has led to a near-universal application of accessible devices at intersections and along the roadway; however, financial constraints have limited the ability of jurisdictions to retrofit all of their pre-existing facilities to ADA compliance. Central to the Complete Streets concept, however, is the idea that the streets are public spaces usable by everyone. California's progress toward comprehensive ADA compliance is an important measure of its progress toward Complete Streets. Proposed performance measure 2.1 c measures ADA compliance at intersections, rather than entire sections of roadway, for reasons of feasibility, although Caltrans should work toward accessibility on the entirety of its facilities.

Performance measure 2.1d directly tracks the Department's progress toward designing urban arterial projects as Complete Streets. Although this measure might seem redundant per the other proposed measures, it is the sole measure that considers all modes and travelers simultaneously. If Caltrans is making improvements on each of the other measures proposed here, this measure will also steadily improve. To determine if the facility qualifies as a Complete Street, Caltrans should adopt a scorecard that can be used in the final design phase of project development.

While the existence and design of a facility is important, the decision to walk or bike depends on a wide range of factors. Performance measures 2.1e and f count the actual number of trips made by pedestrians and bicyclists on urban arterials. This measure accounts for exposure and ensures that traffic safety is not improving due to fewer non-motorized trips.

## DELIVERY

***Caltrans' Delivery Goal: Effectively deliver quality transportation projects and services.***

No new objectives or performance measures are proposed for Delivery.

## STEWARDSHIP

The environmental literature suggested that trees in urban areas tend to be overwhelmingly beneficial for communities. Particular findings include significant benefits in terms of air pollution mitigation (after accounting for maintenance) from public trees in urban areas over their lifetimes. Trees were found to produce savings ranging from approximately $5 to $55 per year, from small to large. Including benefits such as groundwater retention and potential energy savings brings the potential benefits up to $90/year per tree in some places *(56-59)*. Other studies have shown that urban shade trees contribute substantially to reducing emissions, energy usage, and the urban heat island effect, as well as improving human comfort *(60-65)*. The presence and number of street trees has also been found to positively influence the propensity to walk along a street *(29, 66)*.

***Caltrans' Stewardship Goal: Preserve and enhance California's resources and assets.***

Proposed CGS Objective 4.1: *Annually increase the total mileage of urban arterials designed to minimize negative environmental impacts in accordance with Green Streets principles. By 20XX, all urban arterials are designed as Green Streets.*

*PM 4.1a: Ratio of pervious to impervious surfaces on Caltrans urban arterials, including medians, buffer strips, and tree boxes.*
*PM 4.1b: Percent of total urban arterial lane mileage with tree canopy coverage.*

Caltrans' current performance measures for Stewardship primarily gauge pavement and bridge conditions, equipment availability, and the obligation of some types of funding. Although maintaining facilities is important, Stewardship should be viewed more broadly as the Department's responsibility to the users and communities where Caltrans facilities are located. Caltrans has a responsibility to Californians to broaden its approach to Stewardship and recognize the important role that it plays in the protection and preservation of the State's natural resources. Proposed performance measures 4.1a and b allow the Department to work towards its Stewardship Goal to "Preserve and Enhance California's Resources and Assets" more holistically.

To become a successful steward of the State's resources, Caltrans should incorporate Green Streets principles into the design of urban arterials. Green Streets are designed with the maximum canopy coverage and permeable surfaces practicable. These principles are incorporated into this proposed performance measure framework because of the role that greenery can play in improving the local environment as well as traveler experience on urban arterials. Trees in particular can enhance corridor aesthetics and improve the thermal equivalent index by creating shade, thus attracting people to walk and bicycle through a business district and possibly reducing the urban heat island effect through shaded pavement and fewer automobile trips.

Proposed performance measure 4.1a measures the ratio of pervious to impervious surfaces on Caltrans urban arterials. This ratio will improve with each new planted median strip, buffer, and tree that Caltrans incorporates into its projects. Performance measure 4.1b measures the urban arterial lane mileage with tree canopy coverage. Canopy coverage is an important part of the pedestrian experience and is also a measure of the potential environmental benefits a tree-lined street provides.

Proposed CGS Objective 4.2: *By 20XX, all Caltrans urban arterials meet a baseline for non-motorized facility quality.*

*PM 4.2a: Percent of urban arterial sidewalk mileage in fair or better condition.*
*PM 4.2b: Percent of urban arterial bicycle lane mileage in fair or better condition.*

As part of their existing Performance Measure framework, Caltrans monitors distressed pavement through an annual pavement survey. The Department also monitors the maintenance of road striping, guardrails and the overall roadway. There is no measure, however, specifically for the upkeep of bicycle and pedestrian facilities. To meet the mandate of the Complete Streets Deputy Directive, Caltrans must broaden its Stewardship objectives to include maintenance of all facilities, including sidewalks and bicycle lanes.

For pedestrians, cracks or gaps in the sidewalk can be a tripping hazard and create a barrier for people with disabilities, discouraging or preventing them from using a facility. For bicyclists, the condition of the pavement and maintenance of the facility can play an important role in a person's decision to ride. Failing pavement conditions in a bicycle lane can create uncomfortable and unsafe conditions, and if litter or debris from the roadway collects in bicycle lanes, the appeal and performance of the facility is diminished. Also, failing to maintain pavement markings for bicycle lanes may lead to confusion on the roadway that could threaten cyclists' safety. As with all transportation facilities, maintenance and upkeep are essential to the function of pedestrian and bicycle travelways.

## SERVICE

***Caltrans' Service Goal: Promote quality service through an excellent workforce.***

> Proposed CGS Objective 5.1: *Annually increase the number of Caltrans management, design, and maintenance personnel trained regarding Complete Streets principles and Green Streets principles, with the goal of 100% trained.*
>
> *PM 5.1a: Number of personnel trained in Complete Streets principles.*
> *PM 5.1b: Number of personnel trained in Green Streets principles.*

Since the design and maintenance of bicycle and pedestrian facilities has not always been central to the work of Caltrans, many agency employees will need special training in order to implement projects that work toward Complete Streets. Especially since the selection and design of the most appropriate bicycle or pedestrian treatment will vary from site to site, designers must have expansive and current knowledge of best practices in facility design and function. The same is true for maintenance of facilities and collection of data related to bicycle and pedestrian travel. For this reason, it is essential that Caltrans work to expand the capacity and knowledge of the design, maintenance, and management staff on a variety of issues that relate to facilities for non-motorized users. Caltrans may choose to offer its own trainings or take advantage of outside opportunities.

Caltrans staff will also need to be trained on designing, building, and maintaining Green Streets. The Green Streets movement is still evolving and may not offer a variety of specific training programs, but there are a range of landscape programs that would allow Department staff to work towards meeting the new objectives that relate to tree canopy coverage and permeability.

## 4. CONCLUSION & NEXT STEPS

The *Complete, Green Streets Performance Measures Framework* presented in this article is meant to provide Caltrans with the supplementary measures needed to monitor pedestrian and bicyclist safety and the environmental health of its urban arterials. The next step is to test these measures on a transportation corridor and adjust them as needed; this will be done over the next two years through a project with the Traffic Safety Center at UC Berkeley. After the framework has been field-tested and adjusted, it should be ready for adoption by Caltrans and other transportation departments around the country, which can then begin to set targets and gather the data necessary to measure performance.

The result of implementing the proposed *Complete, Green Streets Performance Measures Framework for Urban Arterials* should be a Caltrans roadway system that better accommodates pedestrians and bicyclists and contributes to environmental sustainability and community vitality through increased multimodal mobility, stormwater retention, air pollution interception, beautification, and shade production. If adopted, these measures will provide State taxpayers a way of holding the government accountable in their role as stewards of valued community spaces, and allow Caltrans to demonstrate significant leadership within the transportation field.

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