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16. ABSTRACT

The purpose and goal of the charrette was to explore the idea of redefining ITS evaluation methods to help make the case that ITS projects provide environmental benefits, and that they should therefore be eligible for funding that is earmarked for environmental improvements. This charrette brought together Caltrans, MTC, and other experts from the region to redefine how ITS projects advance state and regional environmental sustainability goals. In doing so, a secondary goal of this charrette was to enhance the eligibility of these projects for federal and state funding opportunities. ITS America assisted Caltrans and MTC by bringing together experts in the transportation, policy, and environmental sustainability fields to help redefine ITS evaluation. This report provides a summary of that charrette, and is divided into sections based on the sessions that occurred during the charrette. The sections of the report are 1) Environmental Funding Sources, 2) Performance Measures, 3) Analytical Tools and Methods, 4) Data Needs and Data Management, and 5) Overall Recommendations and Next Steps.

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DISCLAIMER STATEMENT

California Charrette

Redefining ITS Evaluation for Environmental Sustainability

Submitted to the California Department of Transportation and the Metropolitan Transportation Commission

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Acronyms

AB- Assembly Bill

AHSC- Affordable Housing and Sustainable Communities Program

Cal B/C- California Life-Cycle Benefit/Cost Model

CalEPA- California Environmental Protection Agency

CalSTA- California State Transportation Agency

Caltrans- California Department of Transportation

CARB- California Air Resources Board

CV- Connected Vehicle

GGRF- Greenhouse Gas Reduction Fund

GHG- Greenhouse Gas

HSRA- High Speed Rail Authority

ICM- Integrated Corridor Management

ITS- Intelligent Transportation Systems

MAP-21- Moving Ahead for Progress for the 21st Century

MPO- Metropolitan Planning Organization

MTC- Metropolitan Transportation Commission

OPR- California Governor's Office of Planning and Research

SAFETEA-LU- Safe, Accountable, Flexible, Efficient Transportation Equality Act: A Legacy for Users

SANDAG- San Diego Association of Governments

SB- Senate Bill

SCS- Sustainable Communities Strategies

STIP- State Transportation Improvement Plan

TIP- Transportation Improvement Plan

VMT- Vehicle Miles Traveled

Purpose of the Charrette

The purpose of the *Redefining ITS Evaluation for Environmental Sustainability Charrette* was to bring together Caltrans, MTC, and other experts from the region to redefine how Intelligent Transportation Systems (ITS) projects advance state and regional environmental sustainability goals and, in doing so, enhance their eligibility for federal and state funding programs. The Intelligent Transportation Society of America (ITS America) is the consultant assisting Caltrans and MTC in this effort.

This document presents the process, proceedings, findings, and recommendations from the charrette. The charrette was organized by the California Department of Transportation (Caltrans) and the Metropolitan Transportation Commission (MTC), and was facilitated by ITS America. Through joint outreach, expert participants from leading private, academic, and public agencies were invited to share their experiences on environmental sustainability pertaining to ITS projects.

The primary audience for this document is Caltrans, MTC, and other participants of the charrette. The secondary audience is the participants representing other public agencies in California, councils of governments, private companies, and academia interested in the intersection of environmental sustainability and transportation.

Executive Summary

California is the first state to mandate long-term requirements aimed at reducing greenhouse gas (GHG) emissions. With the passage of Assembly Bill 32, California has set the stage for a state-wide shift in priorities aimed at environmental sustainability, including GHG reduction targets. The transportation sector, which is the largest source of GHG emissions, has a significant role in this move toward sustainability.[1] Reducing GHG emissions from transportation sources requires an inclusive look at how Intelligent Transportation Systems (ITS) projects benefit the transportation network and advance state and regional environmental sustainability goals. The purpose and goal of the charrette was to explore the idea of redefining ITS evaluation methods to help make the case that ITS projects provide environmental benefits, and that they should therefore be eligible for funding that is earmarked for environmental improvements.

The charrette took place on May 11, 2015 at the MTC Auditorium in Oakland, CA. This charrette brought together Caltrans, MTC, and other experts from the region to redefine how ITS projects advance state and regional environmental sustainability goals. In doing so, a secondary goal of this charrette was to enhance the eligibility of these projects for federal and state funding opportunities. ITS America assisted Caltrans and MTC by bringing together experts in the transportation, policy, and environmental sustainability fields to help redefine ITS evaluation. This report provides a summary of that charrette, and is divided into sections based on the sessions that occurred during the charrette. The sections of the report are 1) Environmental Funding Sources, 2) Performance Measures, 3) Analytical Tools and Methods, 4) Data Needs and Data Management, and 5) Overall Recommendations and Next Steps.

The discussion, recommendations, and feedback received from the charrette participants were diverse in applicability to ITS projects and the transportation industry, but specific enough to provide the following near-term suggestions that can be utilized by regional and state agencies to advance their environmental sustainability goals.

One recommendation made by charrette participants addressed the geographical extent of typical ITS evaluations. Environmental benefits need to be recognized across jurisdictional boundaries because the environmental impacts from various ITS projects affect the region and span across jurisdictional boundaries. Performance measures, evaluation methods, and data need to be consistent within and across multiple jurisdictions to demonstrate a regional benefit from the implementation and maintenance of ITS solutions.

[1] California Environmental Protection Agency Air Resources Board. “California Greenhouse Gas Emission Inventory 2000-2012; 2014 Edition.”< http://www.arb.ca.gov/cc/inventory/pubs/reports/ghg_inventory_00-12_report.pdf>.

Another recommendation made was to develop guidance on near-term versus long-term analysis needs tailored to specific ITS solutions. Participants also agreed that is important to develop a long term strategic vision for ITS.

The participants also recognized that ITS projects and solutions are applicable to a myriad of problems that the transportation infrastructure faces. Another recommendation is the need to determine which ITS solutions are most beneficial to the environment and accurately quantifying the benefits is desired amongst the transportation and environmental community. The ability to quantify the benefits of ITS projects requires a change in the approach used to quantify the environmental benefits as the primary benefits of a given ITS project, instead of being derived benefits from capacity improvements. Capturing these benefits within the analysis methods and simulation models today may be possible, but agencies typically lack the expertise and staff necessary to interpret the analysis.

ITS is inclusive of all modes of travel providing an immediate opportunity to demonstrate and quantify environmental benefits for different transportation modes. Of particular agreement amongst the charrette participants was the quantification of GHG emission reductions experienced by heavy-duty vehicles compared to passenger vehicles will most likely prove to be favorable in obtaining additional environmental funding for ITS projects. It is also important to be able to capture mode shift enabled by ITS strategies. While data may be limited for other transportation modes such as bicycles and pedestrians that may also be benefiting from ITS projects, providing a defensible argument for all of the modes is possible.

The report further describes the many suggestions and possible solutions for redefining ITS evaluation for environmental sustainability. These suggestions are intended to be used by the audience of this report as they are applicable to the audience’s interest and needs. The charrette and this report did not attempt to provide a single answer for the stated problem, but instead sought to provide insight into what can be changed now, what needs to be changed for the future, and the ability for Caltrans and MTC to implement some of the suggestions.

Introduction

The State of California is one of the leading states in the nation in environmental policies aimed at reducing greenhouse gas (GHG) emissions. Since the passage of the California Global Warming Solutions Act (Assembly Bill 32) in 2006, state agencies have been working to reduce GHG emissions back to 1990 levels. The magnitude of the GHG emissions reductions called for in California state legislation requires thorough consideration of all emission reductions strategies. The transportation sector is the largest source of GHG emissions in California, contributing to 37 percent of the state's total[2]. Thus, the transportation sector plays a pivotal role in the reduction of GHG emissions.

Intelligent Transportation Systems (ITS) technologies aimed at reducing congestion have traditionally focused on improving traffic flow through transportation system management strategies to reduce congestion and delay. As technology and evaluation methods have evolved, the use of vehicle miles traveled (VMT) and life cycle analysis are now being considered as best practices and/or viable alternatives to traditional measures and to determine the environmental benefit of an ITS project. There is considerable movement in California and the nation to change models from a delay-based analysis to a VMT-based analysis.

ITS evaluation methods have historically focused on operational improvements, such as reducing travel time, which ITS projects bring to either a specific corridor or a region. Reducing the amount of time people spend in congestion has been thought to produce positive impacts in reducing GHG emissions. While traditional evaluation methods and assumptions might be valid for operational measures of effectiveness, there seems to be a lack of performance measures, analysis, and data with which to document environmental benefits, thus preventing ITS projects from being eligible for environmental funding programs.

Environmental sustainability is highly dependent on alternative forms of transportation beyond the single occupant vehicle. ITS is becoming increasingly relevant in providing benefits to users of all modes of travel including transit riders, bicyclists, and pedestrians. The quantification of benefits, especially environmental benefits of ITS technologies for multiple modes of travel, is still an area that is being defined as new data become available and analysis methods are refined.

Reducing GHG emissions from transportation sources requires an inclusive look at how ITS projects benefit the transportation network. In an effort to engage relevant experts in the ITS and environmental communities, ITS America organized and conducted a charrette by bringing together experts in the transportation, policy, and environmental sustainability fields to help redefine ITS evaluation. The charrette occurred on May 11, 2015 at the MTC Auditorium in Oakland, CA. This charrette brought

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[2] California Environmental Protection Agency Air Resources Board. "California Greenhouse Gas Emission Inventory 2000-2012; 2014 Edition."< http://www.arb.ca.gov/cc/inventory/pubs/reports/ghg_inventory_00-12_report.pdf>.

together Caltrans, MTC, and other experts from the region to redefine how ITS projects advance state and regional environmental sustainability goals. In doing so, a secondary goal of this charrette was to enhance the eligibility of these projects for federal and state funding opportunities.

Session 1: Environmental Funding Programs

Background and Read Ahead Material

The overall goal of the charrette was to redefine how ITS projects advance state and regional environmental sustainability goals. The first session, entitled "Environmental Funding Programs," was meant to briefly identify various environmental funding programs for which ITS projects may be eligible. Given that the State of California has many funding sources, the focus of this session centered on differentiating between traditional transportation funding sources and funds directed toward environmental sustainability. Since available funding sources often cover a broad range of projects, the discussion also focused on how to make ITS projects more competitive or complementary to existing projects that currently receive such funding. Most charrette participants were already aware of the funding sources available for transportation projects because of their experience in this field. The discussion of this session did not just focus on the funding sources that are mentioned in this document, but also included discussions on the measures and requirements needed to secure funding.

Funding Sources

Recent legislation and environmental funding opportunities, including AB 32, SB 375, and Cap and Trade funds, allow for the possibility of using VMT-based analysis to measure GHG emissions reductions to demonstrate a project's eligibility. Focusing on quantifying benefits in these terms could facilitate additional environmental funding opportunities for ITS projects in the State of California. The following are some of California laws dedicated to environmental policies:

AB 32: Global Warming Solutions Act

Proceeds from cap-and-trade auctions play a crucial role in achieving the overall goals of AB 32. Proceeds from these auctions are deposited into the Greenhouse Gas Reduction Fund (GGRF), which invests in reduction-based programs focused on renewable energy, energy efficiency, and advanced vehicles, among others. During the 2013-14 cycle, state auction proceeds totaled $832 million, of which approximately $600 million was allocated to transportation programs such as a High Speed Rail Project for the California High Speed Rail Authority (HSRA), the Transit and Intercity Rail Capital Program for the California State Transportation Agency (CalSTA), and the Low Carbon Transit Operations Program for Caltrans.

Starting in 2015, the number of sectors subject to emissions caps has been expanded to include all transportation fuel providers. Therefore, funds in the GGRF are expected to increase, resulting in more resources with which to fund green transportation efforts. In order to receive appropriations from

GGRF, an agency must demonstrate how the project would reduce GHG emissions. To do so, an agency must provide the following:

- A description of the proposed use;
- An explanation of how the project furthers the regulatory purposes of AB 32;
- A description of how a proposed expenditure will contribute to achieving and maintaining GHG levels;
- A description of how the agency considered the applicability and feasibility of other non-GHG reduction objectives; and
- How the agency will document results to comply with AB 32.[3]

SB 375: Sustainable Communities Act

California Senate Bill 375 mandates regional GHG targets adopted by CARB and regional development of sustainable community strategies to achieve targets. While AB 32 is focused on reducing GHG across all sectors, SB 375 takes direct aim at decreasing the emissions caused by the transportation sector. Through the use of Sustainable Communities Strategies (SCS), SB 375 calls on metropolitan planning organizations (MPOs) to develop more efficient land use and transportation plans focused on reducing VMT. A mix of methods is likely to be used by MPOs to create SCS, including:

- Transit development;
- Transportation network improvements;
- Travel demand management;
- Transportation system management;
- Variable pricing;
- Land use policies; and
- Infrastructure programs.[4]

In order to meet the requirements of SB 375, a MPO must quantify the emissions benefit of a proposed SCS. CARB is responsible for evaluating both the methods proposed to reduce GHG by a particular MPO, as well as the expected levels of reduction.

SB 535: Disadvantaged Communities

California Senate Bill 535, an addendum to AB 32, requires 25 percent of the proceeds from the GGRF to be directed towards disadvantaged communities while still contributing to the overall reduction of GHG.

[3] State of California "Cap-and-Trade Auction Proceeds Investment Plan: Fiscal Years 2013-14 through 2015-16" May 14, 2013.

[4] Menzer, Mitchell B. and Ryan Trahan. "The California Air Resources Board Sets Ambitious Greenhouse Gas Emissions Reduction Targets Under SB 375", October 2010.

To accomplish these goals, two funding sources that contribute to transportation projects including ITS projects are:

- Sustainable Communities Planning Grants and Incentives Program; and
- Affordable Housing and Sustainable Communities (AHSC) Program.

Implemented by the Strategic Growth Council, the AHSC Program addresses the goals of both AB 32 and SB 535 by funding land-use and transportation projects that support low-carbon transportation options. This program also links residential areas, major employment centers, and other key destinations to accessible, reliable, affordable, safe, and comfortable transit and active transportation options.[5] Eligible transportation projects primarily have a transit focus that must be implemented in or near disadvantaged communities as designated by SB 535. In general, the projects must expand on an existing capital project or must propose new planning that accomplishes one of the following:

- Demonstrable VMT reductions through fewer or shorter vehicle trips; or
- Demonstrable mode shift to transit use, bicycling, or walking by integrating Qualifying High Quality Transit systems.

Charrette Discussion

This session began with a presentation by Dr. Steven Cliff, the Assistant Director for Sustainability at Caltrans. His presentation provided an overview of Caltrans' sustainability efforts and how those efforts align with the goals of ITS. Dr. Cliff began his presentation with a summary of the political landscape in California, discussing the major legislation that impacts the deployment of transportation projects. AB 32, SB 375, and California's Transportation Plan (SB 391) all mandate GHG reductions on some level. Therefore, in planning for the future, Caltrans has adopted a sustainability goal to "make long-lasting, smart mobility decisions that improve the environment, support vibrant economy, and build communities." In his presentation, Dr. Cliff recommended that transportation agencies should align ITS investments with sustainability though the shared goals of reducing GHG emissions, reducing VMT per capita and multi-modal sustainability. To do so, performance measures should include sustainability-related measures such as non-auto mode share, pollutant emissions, and livability scores. Overall, the goal of ITS is moving people in a more efficient way. In developing transportation projects to better move people, transportation agencies can concurrently work toward California's overall sustainability goals.

[5] Strategic Growth Plan. "Affordable Housing and Sustainable Communities Program –Program Guidelines." State of California. January 10, 2015.

Other Funding Sources

Transportation project funding is often tied to measurable before-and-after data. The aforementioned are three direct funding sources that pertain to ITS projects. The following are additional funding sources or legislation that could potentially impact the way that transportation projects receive funding:

- SB 39: California Transportation Plan;
- SB 1077: Vehicle Road Charge Pilot Program; and/or
- MAP-21.

Session #1 Takeaways

While the goal of each session was not necessarily to build consensus, the discussion generated during this session culminated in several common areas of improvement for transportation agencies. The following takeaways are for the consideration of Caltrans and MTC when moving forward with future ITS projects.

Takeaway #1: Align goals with existing environmental programs

The initial goal of this session was to understand how ITS initiatives perform when compared to other strategies vying for funding in climate change or other environmentally-focused funding programs. As discussion began among charrette participants, however, it quickly became apparent that a more advisable strategy is to work in conjunction with existing environmental programs. Transportation organizations should align investments by creating shared goals with other organizations such as CalEPA, CARB, and the California Governor’s Office of Planning and Research (OPR). These organizations already have strategies in place to secure funding. Therefore, aligning the goals of ITS projects with their strategies would complement existing projects and possibly secure partial funding for ITS projects.

Takeaway #2: Combine traditional funding sources with non-traditional sources

Competing against the financing needs of road repair and other infrastructure improvement programs has long been an impediment to ITS deployment. Another crucial recommendation was to combine traditional funding sources with sources that are transportation-specific. One example was to combine traditional funding sources with pricing mechanisms such as tolling as an option for funding ITS projects. Allocating a percentage of highway tolls to be dedicated to ITS projects with the ability to reduce GHG emissions is another option for securing additional revenue for ITS.

Takeaway #3: Quantify the environmental benefit that heavy duty vehicles experience from ITS deployments

Sustainability funding seeks to reduce GHG emissions regardless of the particular mode of travel. Emissions from trucks and heavy duty vehicles have been identified as a large source of GHG emissions with corresponding funding sources that seek to reduce the emissions from heavy duty traffic. The improvements made on transportation networks by ITS projects can show quantifiable benefits for heavy duty vehicles. Quantifying the sustainability benefits for heavy duty vehicles resulted in smoother traffic flow, reduced congestion, and improved operations due to the deployment of ITS should be documented, and corresponding funding sources should be explored.

Takeaway #4: Identify key stakeholder groups that benefit from ITS projects.

California Senate Bill 535 requires 25 percent of cap and trade funding to be invested in disadvantaged communities as a way to promote social equity and equal access for all people. ITS projects, such as transit and active traffic management, located in disadvantaged communities complement California's overall sustainability goals. Therefore, it is crucial to identify the various stakeholders that would benefit from the deployment of an ITS project during the planning process.

Session 2: Performance Measures

Background and Read Ahead Material

The second session focused on performance measures of ITS projects. Because ITS evaluation methods have historically focused on the operational improvements that ITS projects bring to either a specific corridor or a region, this session explored evaluation methods from an environmental sustainability perspective. This session sought to determine which performance measures are most critical for environmental sustainability goals, as well as how to quantify the benefits and cost associated with environmentally-focused ITS projects.

Funding and Performance Measures

ITS projects have relied on short-term "before and after" studies as the primary way to determine the effectiveness of a project. However, it is also important to consider long-term performance measures, as these can be tied to funding requirements. Certain funding streams such as Statewide Transportation Improvement Programs (STIPs) and Transportation Improvement Programs (TIPs) all have longer-range goals that account for such things as population growth and increased congestion. For example, one ITS project that could receive funding from a STIP may need to demonstrate how it is moving a particular region toward long-term transportation goals. Furthermore, a significant component of MAP-21, in comparison to its predecessor SAFETEA-LU, was the addition of performance measures as a way to improve accountability. MAP-21 required the U.S. Department of Transportation (U.S. DOT) to create a set of performance measure that works toward common national transportation goals, including environmental sustainability.[6] While MAP-21 is set to expire, the next transportation funding bill will likely keep long-term performance measures as a funding requirement for federal dollars.

Performance Measures

Caltrans and MTC are currently utilizing a variety of performance metrics, tools, and evaluation techniques to determine the potential for transportation projects to reduce GHG emissions and other pollutants. The evaluation techniques utilized by Caltrans and MTC are among the leading techniques in the nation to evaluate transportation for the region and the state. As the definition of ITS expands from transportation system management and operations into travel demand management applications (such as transit incentives, smart parking, bike sharing, etc.), the evaluation of ITS technologies must also evolve. The proliferation of new traffic control devices, transportation management strategies, and "new mobility" applications has dramatically accelerated the generation of transportation-related data, providing the information needed to accurately evaluate the emissions benefits of ITS. The following are performance measures discussed during the charrette that consider sustainable practices. It is important to note that these only represent a fraction of the performance measures used.

Specific Measures

There is a disparity between current ITS performance measures and environmental eligibility criteria. Traditional traffic operations performance measures do not cover the broad spectrum of modes of transportation. Additionally, they do not touch on sustainability aspects such as accessibility to alternative modes of transportation. Rather, traffic operations performance measures focus on maximizing the throughput of vehicles on a given roadway. Conversely, sustainability performance measures consider all aspects of the planning process, such as measuring a project's ability to protect natural resources, improve public health, expand the economy, and provide mobility to disadvantaged communities.[7] Providing alternative forms of transportation and encouraging mode shift are considered to be environmentally sustainable goals which may reduce GHG emissions. The following measures represent the comparison between the two categories of measurement. It is important to note that this list is not exhaustive of all measures.

[6] Transportation 4 America. "Making the Most Out of MAP-21". http://t4america.org/wp-content/uploads/2012/11/MAP-21-Handbook-Web.pdf

[7] U.S. Environmental Protection Agency "Guide to Sustainable Transportation Performance." http://www2.epa.gov/sites/production/files/2014-01/documents/sustainable_transpo_performance.pdf

Figure 1. Traditional versus Sustainability Performance Measures (ITS America)

Charrette Discussion

This session of the charrette was led by the moderator, Josh Peterman. To begin the discussion, Mr. Peterman posed a general question about the types of performance measures used by the agencies present at the charrette. The following sections are summaries of the discussions that took place at the charrette.

Geographic Scope

A single ITS project, especially in California, can cross the jurisdictions of multiple Caltrans districts, counties, MPOs, and local transportation agencies. Therefore, a crucial distinction that must be determined during the planning process is the geographic scope of a project that would align with the environmental geographic scope of the project. The geographic scope of an ITS project might need to be expanded to evaluate GHG and environmental analysis. A common dilemma is whether or not to measure a corridor versus a region. When measuring a single corridor, often a single agency is involved in the analysis of a project. Conversely, when measuring performance on a regional level, several agencies are often involved, adding an extra layer of coordination. An issue that arises when measuring across regions is a lack of consistency in the measurements used. Coordinating across agencies becomes a crucial first step in the planning and evaluation process when environmental performance measures are considered. A secondary question that is raised when measuring on a regional basis is the determination of how broad a region should be. Defining the regional boundaries that should be included for measuring the reduction of GHG emissions needs to take into account the immediate and neighboring areas which the ITS technology might affect. For instance, Integrated Corridor Management (ICM) incorporates all transportation assets from all modes along a defined corridor to manage the transportation system as a single entity. While the operational geographic scope might only be focused on the main freeway, alternative vehicle routes, and transit options within the area, the environmental geographic scope is inclusive of the neighborhoods around the routes and the directly adjacent areas, even though they are not part of the operational geographic area. Through all these challenges, a major barrier overarching the transportation industry is the correct data being collected regionally that are available to be shared amongst agencies.

Temporal Scope

Another important distinction when considering performance measures is the temporal scope over which a project is measured. The benefits of ITS projects have traditionally been measured with before-and-after studies a year following deployment. One reason for this is because reduction in congestion has been a primary indicator of whether or not a project is successful. Additionally, ITS technologies typically address both recurring and non-recurring congestion. For example, Active Traffic Management as a system might be the most beneficial during non-recurring congestion (i.e. incidents). Comparing the typical emission levels from normal congestion to the congested levels due to an incident with and without the Active Traffic Management system probably provide substantial environmental benefits that can be quantified. This suggestion may also make it easier to define the geographic scope of which the Active Traffic Management system affects in a region.

Short-term studies are also applicable to ITS because the deployment of such projects are relatively new and do not have a baseline comparison model, mostly because ITS projects are often pilot projects for the industry or are new projects in the region. The reporting requirements for these projects require a shorter temporal scope compared to the service life of roadway pavement.

It is not uncommon for state DOTs and other planning agencies develop twenty-, thirty-, and even fifty-year scoping plans. These plans often include long-term goals that the agency will work toward. In such cases, estimating the long-term benefits of transportation projects is validated. Since ITS is technology-based and technology-dependent, the changes that occur are frequent and shorter than twenty years. Technology sectors typically do not try to forecast the benefits on a long-term range. Adapting a technology life cycle assessment to extrapolate the benefits of ITS may be a possible solution in including ITS for future planning.

Session #2 Takeaways

While this session was moderator-led, the conversation quickly elevated to a productive group discussion on the successful and the ineffective performance measures used by Caltrans, MTC, and other present agencies for ITS projects. Keeping in mind the end goal of making ITS projects eligible for wider streams of funding, the following are the major recommendations that resulted from this session:

Key Takeaway #1: Expand the geographic evaluation area

The geographic area that an ITS project or device might affect varies based on the device itself. Expanding the geographic scope beyond the ITS project boundaries in order to quantify the benefits is needed because GHG emissions travel throughout the region. Capturing the correct geographic region for measurement may depend on a particular use case of the ITS project or device. Individual corridors are useful to be evaluated for operational performance measures, but environmental performance measures typically include a broader geographic scope.

Key Takeaway #2: Adjust the temporal evaluation periods

ITS projects are typically deployed to address specific issues related to surface transportation based on events that disrupt the normal or optimal flow of traffic. The evaluation of ITS projects may need to be applied to the specific events within the agency's specific jurisdiction or multiple jurisdictions. If specific events are causing congestion, and as a result an increase in GHG emissions, those events should be documented, tracked, and quantified to provide an evaluation baseline of the benefits from ITS projects. Reducing the time vehicles and people spend in congestion is a great goal, but proving that the ITS project is achieving this goal may require documentation of a historical baseline that is not normally considered in evaluating ITS projects.

Key Takeaway #3: Performance measurement needs consistency across different modes of transportation and atypical partners

An issue with performance measurement is that it varies across mode, agencies, and whose responsibility it is to measure the performance of various transportation projects. One way to avoid inconsistencies is to establish partnerships, especially with non-transportation agencies. Working with organizations such as CalEPA or CARB to establish a set of environmental standards specific to transportation projects would help to align the goals of both sets of agencies.

To achieve this partnership, one recommendation is to create a central repository of performance measures where multiple partners provide the subsequent data collection that crosses agency lines but with a consistently methodology that is acceptable to the environmental sustainability funding programs.

Key Takeaway #4: Access to destinations and mode shift are important

Key ways that environmental sustainability methods achieve the goal of reducing GHG emissions include minimizing the use of a single occupant vehicle or reducing the number of vehicles on the roadway by offering other forms of transportation that are more environmentally friendly. ITS technologies provide a unique platform that enable, enhance, or complement alternative transportation choices and mode shift within a transportation network. Therefore, it is important to assess these impacts as a result of the implementation of ITS technologies.

Key Takeaway #5: Long-term benefits may be quantifiable now

While it is difficult to estimate the impacts of ITS on a long-term basis, participants noted that consideration should be given to document and quantify the ITS benefits for projects that have been in place for over 10 years. Although the devices may have changed or certain strategies adjusted, ITS has been deployed for years and can thus provide insight into a statistically defensible estimation of long-term benefits. An example of this is signal coordination, instead of comparing the specific travel times of individual corridors, comparing and evaluating the amount of congestion to the increase in volume and mix of vehicles on the roadway with historical environmental data can possibly provide insight into the positive environmental effect from the deployment of ITS projects.

Session 3: Analytical Methods and Tools

Background and Read Ahead Materials

Evaluating performance measures requires the use of analytical tools and models. This session sought to answer questions regarding the best methods to use for the analysis of ITS projects, as well as the potential challenges and barriers to using various analytical tools and models. The primary tools and methods discussed during this session include cost benefit analysis, life cycle analysis, and simulation models. Life cycle analysis was discussed as a possible new method of analysis within ITS and transportation, but many charrette participants were not familiar with this analysis method. However, there was a favorable indication for life cycle analysis to be considered as a possible new analytical method (through subjective audience feedback or lack of opposing feedback).

Data aggregation and visualization are also growing fields in the transportation industry. Utilizing GIS systems and multiple data sources to provide contextual information to complement the typical data sources (volume and speed) that might be obtained through cell phones or third party aggregators is promising for an agency to obtain a greater return on investment.

Benefit-Cost Analysis

The analytical models discussed above require the use of complex software, knowledge of the software limitations, and staff or consultants that are knowledgeable and capable to run the models. The difficulty is that estimating ITS benefits without these models becomes a challenging task since limited information or tools are available.

Caltrans uses the California Benefit/Cost Model (Cal B/C) to conduct investment analysis of interregional transportation projects and have some ITS projects identified within the tool. Many participants acknowledged the usefulness of the tool for what it was created for. It was noted that there is a check box that calculates the reduction in GHG emissions. However, to date, no one has verified if the assumptions and analysis that calculate the reduction in GHG emissions are acceptable to the requirements of environmental funding programs.

Life Cycle Analysis

Life cycle analysis is an active area of research among the academic community. Researchers have argued that the “total environmental inventory, which includes vehicle non-operational components (e.g., vehicle manufacturing and maintenance), infrastructure components, and fuel production components from design through end-of-life processes” should be considered when assessing the impact of each mode of travel. This life-cycle inventory would then replace tailpipe emissions “as the indicator of total transportation system performance. As a measure of the total environmental impact of a given project, life cycle analysis deserves to be considered for its applicability to ITS projects.”[8]

Charrette Discussion

This session began with a presentation on analytical methods and tools by Lin Zhang, Program Manager for MTC. During this presentation, Dr. Zhang delved into an explanation of the various tool types used in transportation planning. The complexity of the analytical tools was discussed at great length, highlighting the limits of certain tools. Synchro, VISUM, Dynasmart, VISSIM, and Aimsun were among some of the analytical tools that were discussed during this session. Depending on the level of analysis needed, the tools varied from sketch planning tools to macro-level analysis tools. While the merits of each software tool were not discussed, the participants indicated the difficulty of capturing the environmental benefits within these tools mainly related to the evaluation level and tool that is used. For example, a micro-simulation level tool might only contain information on one corridor, but the effect of improving the operations along a single corridor with ITS may have a larger geographic impact than the model has information on. On the other hand, a macro- or mesoscopic simulation tool might have the geographic range to capture the effects of an ITS improvement, but may lack the correct parameters that can be adjusted to best represent an ITS project. Therefore, the resulting macro/mesoscopic analyses will derive the environmental benefits based on approximate changes to capacity parameters within these models, which are not a complete representation of the environmental benefits of ITS projects. The available simulation models for transportation projects today have individual and various limitations in representing the complete environmental benefits of ITS projects.

[8] Scientific Applications International Corporation. “Life Cycle Assessment: Principles and Practice.” May 2006.

Session #3 Takeaways

Key Takeaway #1: Assumptions used in analytical models must be readily apparent to funding agencies

The assumptions that go into an analytical model need to be clearly stated and defensible by being inclusive of considerations required by the particular environmental funding source. Understanding and clearly communicating the assumptions is a big aspect of environmental funding review and thus should be clear in the analytical process.

Key Takeaway #2: Apply previously accepted assumptions and analytical methods to ITS projects

It was also noted that transportation agencies should see if the previously accepted analysis methods can be applied to ITS projects. One audience suggestion was to examine projects already deployed by the EPA or other environmental agencies to serve as a baseline of performance measures and the methods needed for measurement. Previously used assumptions and analytical methods of projects that were successful in obtaining funding from the desired funding sources may be an easier path to follow.

Key Takeaway #3: Analytical methods must focus on mobility, not just capacity

As California Senate Bill 743 (SB 743) is implemented, transportation agencies will be required to change the way transportation projects are analyzed. SB 743 moves away from auto delay and level of service (LOS) as measures of environmental impact. Instead, VMT, VMT per capita, automobile trip generation rates, and automobile trips generated are now acceptable measurements for environmental purpose. Additionally, SB 743 focuses on reduction of GHG emissions, promotion of multimodal networks, and the increased creation of mix land uses.[9] Therefore, when using any of the aforementioned analytical tools and methods, agencies must be cognizant of mobility. When choosing an analytical tool, it should contain inputs for these options, if ITS projects are going to be considered for environmental funding sources.

Key Takeaway #4: Staffing and software expertise are key considerations for analytical tools

ITS projects provide a challenge when trying to accurately model the positive affects an ITS technology might have within the available analytical models. Knowledgeable staff who are aware of the limitations of the software, and are able to interpret and provide valuable insight into the benefits for an ITS project, are valuable but scarce resources. Having staff or consultants who are capable of working the models is a need across the industry.

[9] State of California Governor's Office of Planning and Research. "Preliminary Evaluation of Alternative Methods of Transportation Analysis." 30 December 2013.

Session 4: Data Needs and Data Management

Background and Read Ahead Material

New data sources are permeating the marketplace every day through the development of apps in personal devices such as cell phones, tablets, satellite radio, and personal navigation devices. The impending deployment of Connected Vehicle technologies, which will allow vehicles to capture and send data to other vehicles and the infrastructure, is proving to be a desired additional data source for transportation agencies. Data management is becoming a growing challenge for agencies who seek to utilize the variety and volume of data that is being generated by the various devices. Since many of the data sources are from private companies and third parties, often times, the data only shows one aspect of what an agency might need to track in terms of performance metrics. Therefore, this session sought to determine if appropriate data is available to transportation agencies. Emphasis was placed on the types of data needed for performance assessment, data sources, and data that is unique to ITS.

Data Sources and Management

Data is a broad and diverse field that is constantly evolving within the technology industry and consequentially, the ITS industry. The field has leap-frogged historical patterns of data sources, availability, and diversity, putting it on an exponential growth path that is sure to change the way transportation agencies manage and use data.

One of the difficulties in documenting the full effects of ITS projects is the lack of data sources beyond the traditional volume, speed, and occupancy data that is available today. Origin and destination data and the corresponding mode choice data is considered to be a much needed data source for transportation and ITS projects as those data sources can assist in measuring ITS projects appropriately to match environmental performance measures. Going beyond the typical GHG emissions analysis for transportation projects will require new data sources that are yet to be fully realized and available for the transportation industry.

A potential solution for the State of California to manage multiple data sources from multiple agencies and regions is the Caltrans Performance Measurement System (PeMS). It can serve as a data repository that can be used if data standards, collection methods, and aggregation were agreed upon by transportation agencies, and if data policy agreements were in place to support this endeavor. This potential solution is a viable option as a number of charrette participants indicated that data management is a concern for new data sources and the expected increase in the volume of data for the agency.

Data management is an area that agencies will need to address in the near future. This includes how to handle new data sources, exponential increases in the volume of data, the velocities at which data is transferred, and the policies surrounding what data is private versus what data can be shared with the public. Two state departments of transportation, Utah DOT and New York DOT, are two examples of agencies successfully collecting, processing, and providing open data to the public, while achieving and improving operational efficiencies.

Utah DOT transformed the purpose and way in which they manage their assets across all of its departments, as well as how they share data with the public. Through their asset management program, Utah DOT collected highly accurate and precise mobile LIDAR (light detection and ranging) data along every mile of roadway within their jurisdiction. Along with a change in their data management capabilities, this allowed them to have a central data management system enhanced with GIS for the entire department to use. This allowed Utah DOT to explore reusing the data for roadway design, reducing transportation planning alternative analysis times, and improving asset management processes to be data driven. Utah DOT's data portal can be found here.[10]

New York State and New York DOT began to provide most of their data through their open data portal with the intent to allow the public to find information and aggregate large quantities of data. The open data portal also allows the State to use the tools to enhance public access to government data and provide information to the public with increasing efficiency.[11] Using this data, the State of New York has been able to create heat maps by time, day of week, and time of day at its subway stations using turnstile usage data. They have also used this data to hold challenges with prizes for participants to develop an app. In the past, apps have been created that enables and analyzes rider feedback, provides real-time maps of transit routes, offers multi-mode trip planning, and uses wireless beacons to aid with in-station navigation. Open data can be a platform for agencies to utilize its limited resources in an efficient way while engaging the public.

Recent public sector industries such as public health and public safety have started to take advantage of the immense talent, skills, and desire available from technology developers and members of the general public who are willing to help agencies solve the problems that we all face in our daily lives. With the immense amount of data that is available to transportation agencies, the main challenge that is stifling the transportation and ITS industry may be obtaining the institutional and policy support needed for support.

Charrette Discussion

The fourth session began with a brief introduction on the data needs of transportation agencies by Patrick Son, P.E. Senior Technical Program Specialist at ITS America. Mr. Son began his discussion by

[10] https://maps.udot.utah.gov/ugate/f?p=111:2:0::NO:::

[11] http://www.governor.ny.gov/news/no-95-using-technology-promote-transparency-improve-government-performance-and-enhance-citizen

recognizing the difficulties associated with data management that is unique to transportation organizations. One difficulty that arises is multitude of agencies that are collecting data. With state-wide agencies such as Caltrans and various local transit authorities as well as MPOS all housing their own data, ample data is being collect by agencies; however, not all of this data is being shared amongst organizations. One suggestion during his introduction was to “collect once, analyze many” as a way to address the issue of data sharing.

After the introduction by Mr. Son, the remainder of the session was moderator-led. The following sections are summaries and takeaways of the discussions that took place at the charrette.

Standardization of Data

For the ITS industry, the lack of data standards or adherence to any set industry standards is a constant barrier to the sharing and collection of consistent data across agency jurisdictions and within the ITS industry. Data sources that are now becoming available through probe data and advanced detectors is proving to be promising, but already has limitations that may not be suitable for operational and safety analysis. Consideration should be given to see if probe data sources are acceptable when performing environmental analysis methods independent of operational or safety analysis considerations. Whether or not new probe data sources such as Waze, navigation devices, telematics, and potentially Connected Vehicle data are useful to the ITS industry is not completely clear.

Session #4 Takeaways

Key Takeaway #1: A central data repository will help ensure all ITS projects are evaluated in a consistent manner

The National ITS Architecture and Statewide ITS Architecture were meant to address the issue of data standardization; however, none of the agencies represented during the charrette looked to this as a common source. A central data repository would aid agencies as they attempt to evaluate transportation projects with consistent measures. While standards are needed and useful, data aggregators have the capability to translate data through the use of Application Program Interfaces (APIs).

Key Takeaway #2: Lack of data types remains a limitation of certain performance measures

Current measurement techniques are limited to detecting at the vehicle level. However, as ITS and other detection methods advance, organizations will be able to capture movement at the individual level. This will be a crucial advancement in evaluating whether transportation, specifically ITS projects, are beneficial for mode shift. The ability to capture other modal data, including data about bicyclists and pedestrians, can provide a greater insight into the effectiveness of ITS technologies.

Key Takeaway #3: Lack of geographic data availability remains a limitation of certain performance measures

Related to the availability of the type of data, or lack thereof, performance measures and analysis for environmental benefits may need to cross jurisdictional boundaries. The sharing of data between agencies is encouraged to help agencies document the environmental benefits or work together in securing funding for ITS projects.

Session #5: How Do We Make the Case?

Throughout the day, the charrette relied on group discussion by participants to generate the dialogue surrounding how to redefine how ITS projects advance state and regional environmental sustainability goals. The final session of the day served as a recapitulation of the day's discussions. The goal of the charrette was to assess the current process and procedures used when evaluating ITS projects. In doing so, another goal of the charrette was to examine if these methods align with the eligibility requirements for various funding sources. The discussion throughout the day provided valuable insight into these areas. The final session attempted to summarize and put into perspective the discussion throughout the day and how ITS projects can be represented as eligible for other environmental programs. The following suggestions are from the charrette participants related to the topics discussed throughout the day.

- Performance measures should be consistent across organizations, communities, and jurisdictions. The goal should be to measure the whole impacted network consistently.
- Performance measures will also aid in justifying maintenance for ITS systems.
- Terminology needs to be the same across the industry in order to maintain consistent performance measures.
- ITS projects are generally less expensive compared to traditional roadway projects that increase capacity. The return on investment may be higher for ITS projects due to the low costs when compared to building new roadway capacity.
- Don't overgeneralize ITS and how it is defined to people within and outside of transportation. Messaging without being vague is important for others outside of transportation to understand the benefits of ITS.
- Specific project types and strategies of ITS are better aligned with environmental sustainability goals. Separating these projects and strategies may be beneficial when applying for environmental funding programs.
- Rather than promoting ITS as a solution to all environmental problems, agencies should identify a single, measureable environment impact that ITS is solving and use that impact to promote

ITS. Explaining the benefits of ITS in a singular way would put ITS into context of when it is used and how it can make a difference to the environment.

- Work in conjunction with existing environmental programs rather than competing against them for funds.
- Review environmental funding program requirements and how programs within CalEPA, for example, are evaluated.
- Aligning ITS projects with the Complete Streets effort is another strategy to secure funding.
- Positive impacts to individual communities should be properly communicated. Citizens need to see tangible benefits to projects which impact their community and use their tax dollars.
- Employing staff trained to interpret transportation data and having dedicated staff just for data analysis are two issues that further hinder agencies from deploying more ITS projects.
- The average citizen does not know enough about ITS. If the benefits of ITS are explained in metrics such as “lives saved” or “time saved,” the public may be more amenable to spending taxpayer dollars on ITS projects.
- Consider instrumenting a pilot corridor that can provide the necessary information for the different environmental, operational, and safety analysis that is needed. This may prove to be an industry benefit as agencies struggle to know what type of data is needed.

Collaboration Opportunity

Potential Working Group with OPR, CARB, and CalEPA

A major recommendation throughout each session was the need for collaboration among all agencies working toward statewide sustainability goals. Charrette participants from OPR, CARB, and CalEPA expressed the possibility of creating a working group with transportation agencies to explore the topic of demonstrating the environmental benefits of ITS. This group would continue the conversation and strive to answer some of the questions that have not been answered in the industry and at the charrette.

Conclusion

This report sought to synthesize the feedback and information received from the charrette participants who include representatives from the transportation and environmental industries seeking to redefine ITS evaluation for environmental sustainability. The charrette took place on May 11, 2015 at the MTC Auditorium in Oakland, CA. This document presents the process, proceedings, findings, and recommendations from the charrette. Through joint outreach, expert participants from leading private, academic, and public agencies were invited to share their experiences on environmental sustainability pertaining to ITS projects. With the goals of the charrette focused on redefining how ITS projects positively contribute to advancing the state and regional environmental sustainability goals and increasing their potential eligibility of ITS projects for federal, state and local environmental funding programs, this report captured the suggestions and recommendations received from the charrette participants.

One of the major changes that must occur as agencies attempt to meet sustainability goals is the collaboration and cohesive setting of goals and performance measures across jurisdictional boundaries. The environmental goals of a region must extend across jurisdictional boundaries because the impacts to the environment from the transportation sector affect geographic areas that do not stop at jurisdictional boundaries. As transportation agencies continue to strive to reduce GHG emissions and improve the air quality in their respective jurisdictions, the benefits of an ITS project for a transportation agency may not be fully recognized because the geographic scope of the evaluation can extend beyond the project study area.

As performance measures are defined and evaluation measures evolve, so too should the tools and analysis methods. Capturing the full environmental effect for transportation and especially ITS projects requires analysis methods to provide a complete representation of the environmental benefits and not derived from approximate changes to capacity and mobility models. Expanding the geographic and temporal scope of an evaluation study area while changing and increasing the analysis requirements is a monumental task for transportation agencies that are already maximizing all of their resources. However, the hope is that if environmental impacts span across jurisdictions, then transportation agencies can begin to share resources, data, and even analyses that are conducted individually but which may contain the relevant information to capture the full environmental impact of an ITS project.

Environmental analyses for ITS projects are beginning to change the data requirements needed for accurate analysis. The performance measures that environmental funding sources seek are measures that document or contribute to the reduction of VMT per capita, accessibility to destinations, average vehicle occupancy, and accessibility to alternative modes of transportation, to name a few. The data needed to analyze and measure the above environmental performance measures are still difficult to gather but as newer data becomes available, these data sources may prove to be invaluable for the improvement of ITS analyses and capturing a more complete picture of the environmental benefits from ITS projects.

Moving forward, transportation agencies must modify their practices to include environmental sustainability as the state of California has already done. Collaboration and synchronization with other organizations such as state environmental agencies is needed to reach the goals of GHG reduction as an agency, region, and community. This charrette served as an initial discussion on how to change the way the transportation and ITS industry defines the evaluation of ITS projects from a capacity and mobility focus to an environmentally focused approach. While new research and collaboration needs to occur for some of the suggestions in this report to be realized, there are several suggestions from the charrette participants highlighted in this report that can be recognized immediately with the technology today.

Caltrans, MTC, and other agencies are continuing to lead the discussion in defining ITS projects as a positive environmental impact, but will need to collaborate with the environmental industry, academia, and the rest of the transportation industry to achieve the common goal of reducing the environmental impacts of transportation within our regions, state, and nation.

Appendix A: Read-Ahead Materials and Charrette Agenda

(Includes Charrette Agenda)

Redefining ITS Evaluation for Environmental Sustainability Charrette

Read Ahead Materials

May 11th, 2015

Oakland, California

Table of Contents

California Charrette

Redefining ITS Evaluation for Environmental Sustainability

Caltrans, Metropolitan Transportation Commission, & ITS America

AGENDA

9:30-9:40 **Welcome and Introductions:** Patrick Son, P.E.

9:40-9:50 **Purpose of the Charrette:** Moderator, Josh Peterman, P.E.

Topic: This session will present the purpose of the Charrette. The following challenges will be discussed and addressed throughout the day.

- What performance measures should be used to measure ITS project effectiveness?
- What data (type & source) do we need for the performance assessment? And how often?
- What evaluation methods should be used to allow ITS projects to compete for environmental-sustainability funding programs?
- What analytical methods and tools can we use?
- How to make ITS projects priority candidates eligible for federal and state environmental-sustainability funding programs?
- How to bring this ITS evaluation forward and how to inform fund program guidelines or decision-making?

9:50-10:00 **Brief Presentations of local ITS Projects**

- Presentation from Caltrans
- Presentation from MTC

10:00-10:45 **Environmental Funding Programs**

Brief Presentation: Dr. Steven Cliff, Caltrans Assistant Director of Sustainability

Topic: This session will briefly identify various funding programs (federal & state) for which ITS projects may be eligible. Some of the questions to be addressed include:

- What are the funding requirements?
- What specific measures are most important?
- What assumptions are accepted?

How do we make the case?

Group Discussion

10:45-11:00 **Break**

11:00-12:15 **Performance Measures**

Topic: This moderator-led session will discuss ITS performance measures, highlighting the disparity between current ITS performance measures and environmental eligibility criteria. ITS strategies in this Charrette discussion will be mainly focused on the following: adaptive ramp metering (ARM), hard shoulder running (HSR), queue warning, adaptive traffic signals, speed harmonization, integrated corridor management (ICM, or connected corridor), and connected vehicle deployment. Some of the questions to be addressed include:

- Which performance measures are typically used to measure the effectiveness of various ITS projects?
- Which innovative performance measures are critical to ensure environmental sustainable goals, such as life cycle analysis, are being met?
- How do we measure the long term benefits of ITS projects? How do we typically conduct before and after studies?
- How to quantify some of the potential benefits, such as non-recurring congestion, greenhouse gas emissions, and safety?
- What elements should be included in benefits and costs for the Benefit/Cost (B/C) analysis? For example, specific benefits may include travel time savings and reliability, collision reduction, GHG emissions reduction, etc. Specific costs may include capital, design, environmental process, operations and maintenance.

Group Discussion

12:15-1:30 **Lunch**

1:30-2:45 **Analytical Methods and Tools**

Topic: After a brief discussion of traditional operations-based analysis methods, this moderator-led session will explore different approaches to analysis methods and tools, and discuss potential challenges and barriers to using these different approaches. Special data needs for some analysis methods and tools will be discussed. Case studies will be introduced to demonstrate the applications of some of the analysis methods and tools. Some of the questions to be addressed include:

- What analytical methods and tools are available to ITS projects? How are they different than other operational or capacity improvement projects?
- What specific data is needed for some of the analysis methods and tools?
- What are the challenges and barriers to using the analytical methods and tools?

- What new analytical methods and tools are needed?

Group Discussion

2:45-3:15 **Data Needs & Data Management**

Topic: This moderator-led session will discuss various types of data and data sources that would be needed for the performance assessment. Some of the questions to be addressed include:

- What data do we need for the performance assessment?
- What are the data sources?
- How often and how difficult is it to collect these data?
- What data is unique for ITS projects and why is it important?

3:15-3:30 **Break**

3:30-4:45 **How Do We Make the Case?**

Topic: This moderator-led session will discuss how to use the performance evaluations to make the case that ITS projects should be funded by the environmental-sustainability programs. Focusing on California's Cap and Trade program and the reauthorization of MAP-21, this session will discuss some ideas on how to move forward with ITS project performance evaluations and how to inform fund program guidelines or decision-making.

- How to use the performance evaluations to make the case that ITS projects should be funded by the environmental-sustainability programs?
- What are the ideas to bring this ITS evaluation forward?
- How to inform fund program guidelines or decision-making?

Group Discussion

4:45-5:00 **Closing Remarks and Adjourn**

MTC's ITS Deployment Summary

511 Traveler Information Program

The 511 traveler information program provides traffic, transit, ridesharing, bicycling and parking information via the phone (511), web (511.org), and other channels, including, regional transit hub sign displays and other products provided by third-party providers. The information provided through 511 represents the efforts of ongoing collaboration and coordination with the program's partners, including Caltrans, the California Highway Patrol, the region's transit agencies, the Air District and numerous county and local transportation agencies, and event organizers/venues.

The 511 program must cost-effectively collect, process and disseminate data to provide premier multi-modal traveler information and services that are useful, accurate, and reliable. Responsibility for gathering, processing and dissemination of 511 information should be regionally coordinated and rationally allocated to Bay Area transportation organizations – in both the public and private sectors – according to institutional interest, and ability.

The 511 program provides real-time traffic, parking and transit information services as well as trip planning tools, including the transit trip planner and the Enhanced Trip Planner that provides comparisons of drive-only, transit and drive to transit options. 511 provides online ride matching tools and a bicycling trip planner. 511 also provides data feeds and Application Programming Interfaces (APIs) for use by the developer community, to create other tools and services.

Among its many roles, the 511 program:

- Serves as the go-to source for travelers and media in regional emergencies;
- Partners with many agencies and businesses for regional events; and
- Supports numerous MTC/SAFE/BATA objectives.

Express Lanes Program

Express lanes are specially-designated highway lanes that offer toll-free travel for carpools, vanpools, motorcycles, buses and eligible clean-air vehicles. Solo drivers also have the choice to pay to use the lanes to avoid congestion.

Bay Area transportation agencies are developing a 550-mile network of Bay Area Express Lanes that will be completed in 2035. MTC will convert 150 miles of existing High Occupancy Vehicle (HOV) lanes to express lanes and add 120 miles of new lanes to close network gaps. Ultimately, MTC will operate 270 miles of Bay Area Express Lanes.

Freeway Performance Initiative (FPI) Program

The FPI is a comprehensive program that aims to improve the efficiency, safety and reliability of freeway travel for people and freight through improved freeway operations. FPI's key elements include:

Traffic Operations System (TOS)
To help detect slowdowns and incidents, MTC and Caltrans are installing closed-circuit television cameras, wireless in-pavement sensors and roadside data-relay stations along area freeways. The information gathered will be fed to the Regional Transportation Management Center in downtown Oakland, which will deploy tow trucks and other resources to quickly clear incidents and thereby reduce delays and prevent the occurrence of secondary accidents. The system will alert motorists to incidents through an expanded network of highway advisory radio channels and changeable message signs, along with MTC's 511 Traveler Information System and in-car devices.

Ramp Metering
The metering of freeway on-ramps is not only highly effective in reducing congestion, but these types of projects can be deployed at a fraction of the cost of traditional freeway widening projects — and in a fraction of the time. The FPI program is installing and activating metering lights at nearly 800 entrance ramps, essentially building out the system on Bay Area freeways.

Arterial Management
Maximizing efficiency of the freeway system requires coordination with and optimization of major parallel arterials. The Freeway Performance Initiative will provide funding for MTC's ongoing programs to modernize and synchronize signals along major arterials.

Transportation Management System Program

The objective of the program is to ensure reliability and sustainability of a strong Transportation Management System that can serve as the foundation for future expansion, and to optimize the region's investment across projects and systems.

The Transportation Management System (TMS) encompasses (1) highway operations equipment; (2) critical freeway and incident management functions; and (3) Transportation Management Center (TMC) staff and resources needed to actively operate and maintain both equipment and all these critical freeway and incident management functions.

MTC, in coordination with Caltrans and the California Highway Patrol, have developed a Regional TMS Performance-Based Action Plan, which serves as a roadmap to guide strategic system management investment priorities for TMS operations and maintenance. The Action Plan identifies key corridors that will serve as initial candidates for new strategies and focus, given current resource constraints; these corridors were selected based on a review of accident rates, levels of congestion, levels of ITS infrastructure, and classification as a Lifeline Highway and Recovery Route. The plan identifies preliminary performance targets for these priority corridors and devices that can be used to assess overall performance and measure success. The plan also identifies a timeline and estimated funding proposal for near-term priority projects. MTC, Caltrans, and CHP will update the plan, as appropriate and when needed.

Incident Management Program

The Incident Management Program undertakes planning activities to identify multi-modal system management strategies that will mitigate the effects of non-recurrent congestion caused by incidents that occur along Bay Area corridors. The Incident Management program assesses existing operational and management tools, and demonstrates the benefits and impacts of newly implemented strategies. The program also aims to improve the cooperation, coordination, and communication among Bay Area first responders and partner agencies responsible for incident management.

I-880 Integrated Corridor Management (ICM) Northern Segment project

The purpose of the project is to manage arterial traffic that has naturally diverted due to an incident and route motorists back to the freeway using ITS strategies (e.g., trailblazer signs, cameras) to optimize operations. The project involves coordination with multiple agencies, including Alameda County Transportation Commission, Caltrans, Oakland, San Leandro, and AC Transit.

Bay Area Incident Management Task Force

An interagency committee comprised of staff from the California Department of Transportation (Caltrans) District 4, California Highway Patrol (CHP) Golden Gate Division, the Metropolitan Transportation Commission (MTC) and allied first responder agencies. The goal of the Bay Area IMTF is aligned with the National Unified Goal for traffic incident management, including responder safety, safe and quick clearance, prompt reliable interoperable communications and enhanced inter-agency coordination, cooperation, collaboration and communication.

Columbus Day Initiative (CDI)

MTC is also planning on implementing a suite of next generation operational improvement strategies to address increasing congestion problem in the Bay Area. Through the Columbus Day Initiative, the intent is to reduce vehicle delays, similar to a commuter’s experience during holidays. These operational strategies include adaptive ramp metering, hard shoulder running, connected vehicles, queue warning, and adaptive traffic signals with transit signal priority.

Caltran's ITS Deployment Summary

A CHARRETTE PROPOSAL:
The Charrette should explore how ITS projects such as ATM, ICM and Connected Vehicles can meet sustainability performance measures via verifiable data to improve the environment. By doing so, these projects can qualify for a variety of funding sources including grants from the cap and trade program.

A brief Caltrans research project task description and definition of these topics are provided below.

ACTIVE TRAFFIC MANAGEMENT (ATM):
This goal of this project (Task 2445) is to conduct a limited scale field test of the combined Variable Speed Advisory (VSA) and Coordinated Ramp Metering (CRM) freeway traffic control strategy developed in the recent study. This will determine its ability to increase the effective capacity of a recurrent bottleneck, which addresses an urgent problem for California's congested urban freeways. It will offer a potentially inexpensive way of increasing the achievable capacity of the recurrent bottlenecks that currently limit traffic flow and speed during busy periods. Variable speed limits can either be enforceable (regulatory) speed limits or recommended speed advisories, and they can be applied to an entire roadway segment or individual lanes. Coordinated Ramp Metering based on real-time data and this project will to determine its effectiveness in improving corridor traffic flow through preliminary evaluation based on data analysis.

INTEGRATED CORRIDOR MANAGEMENT (ICM):
The goal of this project (Task 2165) is to provide expertise to augment technical management, software/systems development, and cutting-edge transportation technology innovations to foster the successful design, implementation, and evaluation of the ICM system within the I-15 corridor. ICM will offer an opportunity to operate and optimize the entire system as opposed to the individual networks. ICM enables departments of transportation to optimize use of available infrastructure by directing travelers to underutilized capacity in a transportation corridor. Strategies include motorists shifting their trip departure times, routes, or modal choices, or DOTs dynamically adjusting capacity by changing metering rates at entrance ramps or adjusting traffic signal timings to accommodate demand fluctuations. In an ICM corridor, travelers can shift to transportation alternatives -- even during the course of their trips -- in response to changing traffic conditions.

CONNECTED VEHICLE (CV):
The goal of this project (Task 2297) is to upgrade CV test-bed at the eleven locations on highway 82 (El Camino Real). After the successful completion of this project these eleven locations will be ready for testing, including the radios that can communicate with suitably equipped vehicles in their vicinity. Connected Vehicle technology is a combination of well-defined technologies, interfaces, and processes that combined will ensure safe and reliable system operations that minimize risk and maximize opportunities. CV Technology will create standards for interoperability; security of the system; strategies that address the complexity of human behavior and risks associated with the driver's workload; and processes that define how travelers and equipment become a certified part of the system.

Traffic Light Synchronization Program (TLSP): Proposition 1B was passed by California voters on November 7, 2006, and created the Traffic Light Synchronization Program (TLSP). Proposition 1B provides $250 million, upon appropriation by the Legislature, for TLSP projects approved by the California Transportation Commission (Commission). Caltrans provides a quarterly report to the Commission on the status of progress by the local agencies on completing TLSP work funded by the Proposition 1B bond funds.

The guidelines for the TLSP were adopted on February 13, 2008. On May 28, 2008, the Commission approved 21 traffic light synchronization projects totaling $147,000,000 for the City of Los Angeles and 62 additional traffic light synchronization projects totaling $98,000,000 for agencies other than the City of Los Angeles. At the December 2009 CTC meeting, the Echo Park/Silver Lake project was split in two, resulting in a total of 22 TLSP projects in the City of Los Angeles.

Traveler Information: Traveler Information is rapidly evolving due to new requirements in federal statutes and also the public demand for support of social media. The public can obtain traveler information from Caltrans through four methods:

1) By using the internet web-based application called QuickMap;
2) By connecting with Caltrans' Interactive Voice Response (IVR) system when dialing 1-800-427-7623 on any mobile or landline phone;
3) By accessing the California Highway Information page available on the internet;
4) By logging into the Commercial Wholesale Web Portal (CWWP).

These four systems together are called the California Highway Information Network (CHIN) and they each provide traveler information through different means and formats. Quick Facts:

- QuickMap had 592,053 unique visitors in 2013, viewing 31,178,978 pages.
- The CWWP provided approximately 2,324,180 visitors with data in 2013.
- The 1-800 IVR services approximately 1.6 million callers each year.
- The full motion video webpage had 323,260 unique visitors in 2013, viewing 15,884,740 video streams.

Connected Corridors is a collaborative effort to research, develop, and test a framework for corridor transportation system management in California. The aim is to address and fundamentally change the way the State of California manages its transportation challenges for years to come. Starting with a pilot on Interstate 210 in the San Gabriel Valley, the Connected Corridors program will expand to multiple corridors throughout California over the next ten years.

Connected Corridors is an Integrated Corridor Management (ICM) program that looks at an entire transportation system and all opportunities to move people and goods in the most efficient manner possible—including freeways, arterials, transit, parking, travel demand strategies, agency collaboration, and more—to ensure the greatest potential gains in operational performance will be achieved.

The goals of the Connected Corridors program are to:

- Reduce congestion and improve travel time reliability along fifty corridors throughout the state of California
- Bring together corridor stakeholders to create an environment for mutual cooperation, including sharing knowledge, developing working pilots, and researching and resolving key issues
- Equip traffic managers and first responders with accurate and reliable information and give them the ability to make real-time decisions to quickly improve traffic flow along the corridor
- Encourage, facilitate, and incorporate transit and multimodal travel in the corridor
- Integrate with state, regional, and local environmental, planning, and livability initiatives
- Quantify the success of each CC pilot and the program as a whole via comprehensive performance measures

Long term benefits of Connected Corridors include:

- Improved travel time reliability for travelers and freight transport
- Better transit information and faster travel time for buses through transit signal priority systems
- Faster traffic re-routing following an incident on the freeway or an arterial
- Reduced incidents caused by bottlenecks and improved incident response
- Reduced emissions due to less vehicles idling in traffic and greater use of transit and multi-modal travel
- Reduced congestion and improved performance on California's most complex traffic corridors
- Improve traveler information, mobility, and safety

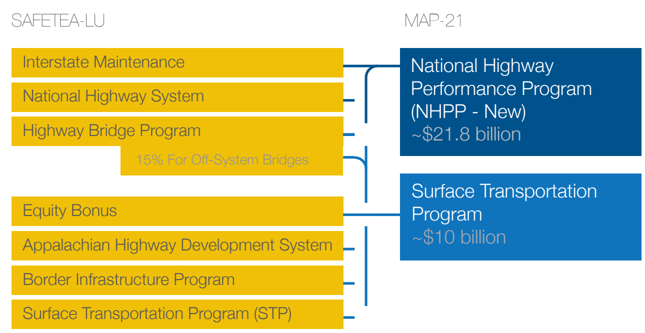
Surface Transportation Program (STP)

The Surface Transportation Program is the most flexible of all the highway programs and historically one of the largest single programs. States and metropolitan regions may use these funds for highway, bridge, transit (including intercity bus terminals), and pedestrian and bicycle infrastructure projects. Under MAP-21, new responsibilities were added to the program though funding was not increased proportionally. **About $5 billion in new responsibilities were added to the STP, but the program was only increased by $1 billion.**

Each year, states must suballocate a portion of STP funds to metropolitan areas over 200,000 in population. This provides regional leaders the opportunity to direct these funds toward local priority projects. Under MAP-21, metro regions will receive approximately the same level of suballocated STP funds as before.

Funding

SAFETEA-LU	**MAP-21**
$8.8B	**$10B**



STP can cover 80 percent of the total cost of a project, with the rest covered by states or localities. States must dedicate an amount equal to 15 percent of their FY2009 Highway Bridge Program apportionment out of the STP program to fix off-system bridges (i.e., bridges not located on a federal-aid highway; generally local streets.) The bridge set-aside totaled $776 million in 2009. This bridge set-aside may not come from the money that states are required to suballocate to metro areas for local priorities.

Eligible projects

Highway and bridge construction and rehabilitation	De-icing of bridges and tunnels
Federal-aid bridge repair	Congestion pricing and travel demand management
Off-system bridge repair	Development of state asset management plan
Transit capital projects	Carpool projects and fringe and corridor parking
Bicycle, pedestrian, and recreational trails	Electric and natural gas vehicle infrastructure
Construction of ferry boats and terminals	Intelligent transportation systems
Environmental mitigation	Border infrastructure projects

How the program works

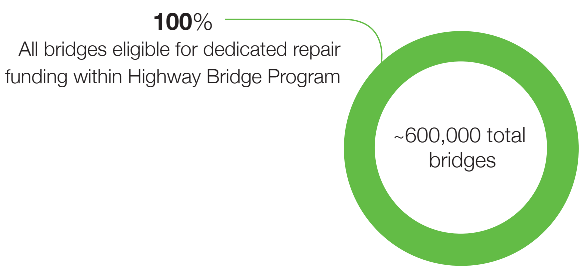
Under MAP-21, STP continues to provide flexible funding to states and metro regions to implement local and state priorities. Metropolitan regions over 200,000 in population will continue to receive a portion of these funds to direct toward local priorities. Though the share that has to be given directly to metro areas decreases from 62.5 to 50 percent of the program, because the STP grew in size, the overall dollar amount that metro regions receive will remain consistent.

The big difference relates to addressing structurally deficient bridges: For the first time, the STP is responsible for the **460,000** federal-aid bridges not located on the National Highway System. Previously, any structurally deficient bridge could be fixed with funds from the Highway Bridge program, which was eliminated under MAP-21 with virtually all of the money rolled into the new National Highway Performance Program (NHPP).

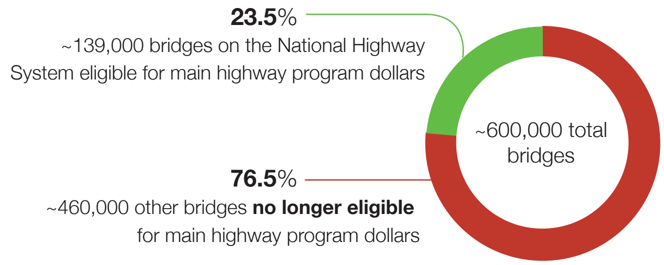
MAP-21 eliminates bridge repair program

And forces three-quarters of all bridges to compete for flexible STP funding

SAFETEA-LU



MAP-21



The problem with this structure is that NHPP dollars can only be spent on the 23 percent of federal-aid bridges located on the National Highway System, ignoring the needs of the over **460,000** bridges not on the NHS.

Thus, the NHPP received all the money for repairing bridges while STP received the responsibility for fixing more than **123,000** structurally deficient bridges not on the National Highway System.

The new responsibility to repair non-NHS bridges is estimated to cost approximately $5 billion. However, STP funding only increased by $1.2 billion. The new burden to repair and rehabilitate deficient bridges will likely make it harder to use STP dollars to fund local priorities — forcing them to compete with the needs of deficient bridges.

The National Highway Performance Program (NHPP - New)

The new National Highway Performance Program provides funding for construction and maintenance projects located on the newly expanded National Highway System (NHS) – which includes the entire Interstate system and all other highways classified as principal arterials.

The NHS used to be composed mostly of roads for traveling across a state or from region to region. MAP-21 expands the NHS to include many other roads that are important for travel **within** a region, adding about 60,000 new lane miles to the NHS.[1]

MAP-21 eliminates the programs with dedicated funding for repair by consolidating the Interstate Maintenance and Highway Bridge Repair programs and shifting these funds to the new NHPP. The new NHPP is now the largest highway program, receiving **58 percent** of all highway formula dollars. States are permitted to transfer up to 50 percent of the NHPP dollars to other programs, including the Surface Transportation Program (STP), Highway Safety Improvement Program (HSIP), and the Congestion Mitigation and Air Quality Improvement program (CMAQ).

NHPP does require what's known as an "asset management plan" to prioritize spending to reach performance targets for the National Highway System.

Funding

SAFETEA-LU funds focused on the NHS[2]	Percentage of total highway formula funding
$18 billion	40 percent
MAP-21 NHPP	Percentage of total highway formula funding
$21.75 billion	58 percent

1 MAP-21 expands the National Highway System (NHS) from 160,000 to approximately 220,000 miles. The expanded NHS includes the Interstate System, principal arterials, designated intermodal connectors (roadways that link to ports, freight transfer stations, and other facilities), and the strategic highway network (roadways that connect to military installations). The expanded NHS will now cover most lane miles of the state highway system.

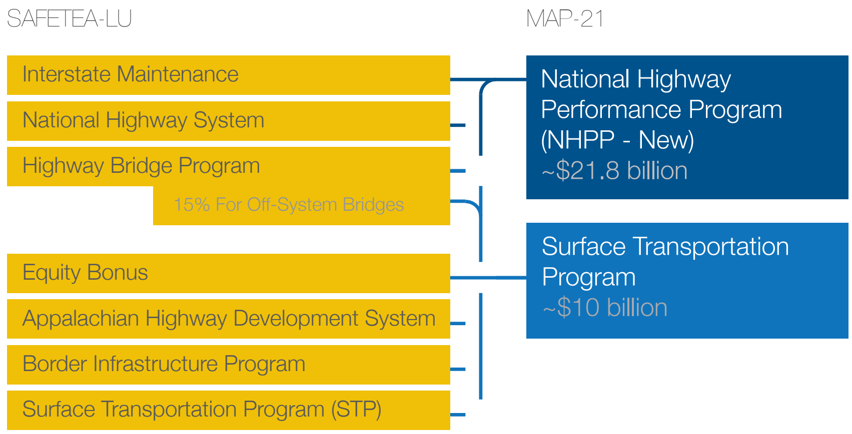
2 This figure includes funding from the Interstate Maintenance, National Highway System, and one-half of the Highway Bridge Program

Eligible projects

The following table presents the most common NHPP project categories. **Unless otherwise noted, all eligible projects must be located on the Interstate or NHS.** Federal-aid and off system bridge repair is not eligible under the NHPP program.

Construction, reconstruction, resurfacing, restoration, rehabilitation, and preservation of highways and bridges	Construction, rehabilitation, or replacement of existing ferry boats and facilities, including approaches, that connect road segments
Bridge and tunnel inspection and evaluation as well as the training of bridge and tunnel inspectors	Safety projects
Transit capital projects (only under certain conditions	Federal aid highway improvements (only under certain conditions)
Environmental restoration and mitigation	Intelligent transportation systems (ITS)
Bicycle and pedestrian infrastructure	

The NHPP will cover 90 percent of an eligible project's cost for Interstate projects and 80 percent for other projects on the NHS. If the project is part of a State Freight Plan and located on the Interstate system, the federal share may rise to 95 percent. If the project is part of the State Freight Plan and on the NHS (excluding the Interstate), then the federal share may rise to 90 percent. Certain safety projects may have a federal cost share of up to 100 percent.



How the program works

MAP-21 dramatically expands the funding for the NHPP program (previously called the National Highway System program) and consolidates the other programs intended for bridge repair and Interstate maintenance. Only projects located on the expanded National Highway System are eligible.

In other words, the largest pot of money in the bill can now only be spent on a very limited set of roadways, which includes the Interstate system and all of the principal arterials in a state. This increases the likelihood that NHPP dollars may be spent on major roadway projects while local roads and bridges struggle to find funding for safety or other improvements.

In addition, the program eliminates dedicated funding for bridge repair. As a result, there are more than 123,000 structurally deficient bridges located on non-NHS roadways that will have to be repaired with funds from other programs — which also means those bridge needs will be competing with other needs for limited pots of flexible money.

It's important to note that states are allowed to transfer up to half of the NHPP dollars to the much more flexible Surface Transportation Program (or other programs), which may be used to fix non-NHS bridges and other projects without having to clear these hurdles.

Performance and Accountability

MAP-21 requires a new focus on performance and accountability that will help prioritize NHPP spending to reach hard performance targets on the National Highway System.

The performance system set up by MAP-21 has two stages. First, the Secretary of Transportation must develop uniform ways to measure performance of the National Highway System. Second, states must set specific, quantifiable targets for each of the performance measures and then chart performance over time. The first report is due within four years and then every two years thereafter.

MAP-21 requires states to develop a risk-based asset management plan for the National Highway System. States take an inventory of their assets and determine the highest priorities for repair and then craft a strategy to best address those issues. The Secretary must recertify the plan and process every 4 years.

To help prioritize spending, the bill also establishes penalties for failure to perform. If a state fails by 2014 to develop a risk-based asset management plan, the federal share of eligible project costs drops down to 65 percent. Also, If a state fails in 2018 to meet minimum Interstate pavement condition standards, they must set aside an amount of NHPP funds equal to their FY09 Interstate Maintenance program apportionment - plus an additional 2 percent for every reporting cycle thereafter. In addition, states must transfer an amount from the Surface Transportation Program to NHPP equal to 10 percent of their FY09 Interstate Maintenance program apportionment.

If the total structurally deficient deck area of NHS bridges exceeds 10 percent of all NHS bridge deck area, then a state must set aside NHPP funds equal to 50 percent of the FY09 Highway Bridge Program apportionment until the standard is met.

Taken together, these steps are intended to ensure that states make progress towards improving the condition of NHS highways and bridges.

Highway Safety Improvement Program (HSIP)

MAP-21 retains the Highway Safety Improvement Program (HSIP) as one of the core highway programs intended to reduce injuries and fatalities on all public roads, pathways or trails. There is a new emphasis on enhanced data collection and performance. And for the first time a "road user" is defined as both a motorized and non-motorized user (i.e., someone walking or biking). These two shifts lay the framework for more effective spending of safety dollars on projects that make roads safer for all users.

Funding

SAFETEA-LU	**MAP-21**
$1.7B	**$2.4B**

Eligible projects

Any project on a public road, trail or path that is included in a state's Strategic Highway Safety Plan and corrects a safety problem such as an unsafe roadway element or fixes a hazardous location is eligible for HSIP funding. Eligible projects include, but are not limited to the following: intersection improvements, construction of shoulders, high risk rural roads improvements, traffic calming, data collection, and improvements for bicyclists, pedestrians, and individuals with disabilities.

MAP-21 does not eliminate any eligible project categories that were previously eligible under SAFETEA-LU. In addition, the bill clarifies that retroreflectivity upgrades, truck parking facilities, safety audits, older driver improvements and systemic safety improvements are eligible expenses. Other non-infrastructure safety projects are eligible for HSIP funding, including safety education, training, and workforce development.

How the program works

The HSIP is guided by a data-driven state strategic highway safety plan that defines state safety goals, ranks dangerous locations, and includes a list of projects.

Under MAP-21, the safety plan is required to improve data collection on crashes and updates to more accurately identify dangerous locations. One important change is the move to use crash rate in addition to the total number of crashes to determine the relative danger of a roadway, intersection, or bike/pedestrian facility. For instance, a particular roadway may not have the highest number of total crashes, but a high number relative to daily traffic counts or total vehicle miles traveled.

Finally, states are required to reassess which design elements make roadways unsafe and they are required to use this updated list as a guide when identifying hazardous locations. These updates should help states prioritize safety spending on fixing the elements that make those roads dangerous for all road users.

Performance and Accountability

For the first time, USDOT will establish performance measures[1] to assess serious injuries and fatalities. States and regions will set targets using these measures, and incorporate those targets into their safety plan as well as into their statewide and regional planning processes.

1 USDOT will establish uniform measures so that all states and territories apply the same methodology. This will ensure that data is comparable across states and over time. In addition, states are required to set a performance target using the uniform measure.

MAP-21 replaces the former reporting structure, which focused primarily on cost needs, with a more comprehensive reporting process. The bill requires states to report on progress made implementing highway safety improvements and the extent to which they have made progress toward their safety targets.

Penalty: If a state has not met or made significant progress toward meeting its safety targets within two years, it must submit a report detailing how it will make progress in meeting performance targets. In addition, the state loses the flexibility to spend safety funding on other non-infrastructure safety projects such as safety education.

High Risk Rural Roads (HRRR): MAP-21 eliminates the $90 million annual set-aside for safety spending on high risk rural roads, or any public road in a rural area identified in the safety plan as having significant safety risks. But these roads won't be neglected. If fatalities on these rural roads increase under MAP-21, states must spend a minimum amount of safety funds on those roads (equal to 200% of the FY 2009 HRRR set-aside).

Older drivers: If serious injuries and fatalities increase for older drivers and pedestrians, a state must specifically incorporate strategies to address the increases in the next safety plan update.

Congestion Mitigation and Air Quality Improvement (CMAQ)

The CMAQ program provides funding for projects that will relieve congestion and reduce pollution levels to help states and metro regions meet federal air quality standards. CMAQ funds may support many different types of projects. However, this program may not fund projects that lead to increased travel by single-occupant vehicles (SOVs). For instance, CMAQ funds may not support construction or expansion of general travel lanes. Instead, CMAQ funds are directed toward projects, programs, and operational strategies that provide residents with transportation options, make the most effective use of existing facilities, and lead to lower pollution levels.

Funding

SAFETEA-LU	**MAP-21**
$2.3 billion	**$2.2 billion**

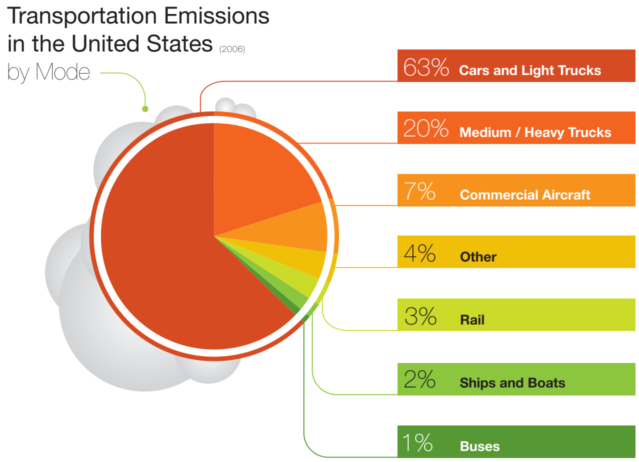
MAP-21 made a significant change, allowing states to transfer up to 50 percent of CMAQ program funds into other programs for other uses. Under SAFETEA-LU, only 20 percent of CMAQ funds could be transferred to other programs. For this reason, it has become more important to communicate to local and state leaders the need to prioritize CMAQ dollars for congestion mitigation and air quality improvement projects.

Eligible projects

The following table presents some of the most common CMAQ project categories, though it is not an exhaustive list. Additional details are available through the CMAQ program guidance: www.fta.dot.gov/documents/cmaq08gd.pdf

Establishment or operation of a traffic monitoring, management, and control facility	Transit capital projects and improved transit services, including operational assistance for new or expanded service for up to 3 years
Projects that improve traffic flow, including projects to improve signalization, construct HOV lanes, improve intersections, add turning lanes	Bicycle and pedestrian facilities
Diesel retrofits of older engines	Variable roadway pricing
Construction of facilities serving electric or natural gas-fueled vehicles	Fringe and corridor parking facilities
Projects that shift traffic demand to nonpeak hours or other transportation modes, increase vehicle occupancy rates, or otherwise reduce demand.	Carpool and vanpool services
Intelligent transportation systems (ITS)	Intermodal freight capital projects

In addition, MAP-21 requires states and metropolitan regions that are labeled as “nonattainment” or “maintenance” areas for PM 2.5 (tiny particulate matter that results from the combustion of fuel) to spend a certain percentage of CMAQ funds on projects that will reduce this harmful pollution.



How the program works

In 1990, Congress enacted a series of amendments that strengthened the Clean Air Act. The following year, Congress passed ISTEA, the transportation law that first established the CMAQ program to provide states with flexible funding for projects that reduce congestion and improve air quality, along with meeting the more aggressive clean air standards of the amended Clean Air Act.

CMAQ funds are disbursed to and within a state based on levels of pollution within an area, and then the state or the region uses that money to implement projects that reduce congestion or improve air quality by investing in the types of eligible projects listed above.

Performance and Accountability

MAP-21 establishes several national goals, including to "enhance the performance of the transportation system while protecting the natural environment."

Within 18 months, the Secretary of Transportation must establish a uniform standard for how states are to measure traffic congestion and transportation emissions. Then, states and metropolitan planning organizations serving regions with a population over 1 million must set performance targets for congestion and air quality. Presumably, these targets will reinforce ongoing efforts to meet Clean Air Act standards (also called National Ambient Air Quality Standards or NAAQS).

To meet those targets, metropolitan planning organizations representing over 1 million in population must develop a "performance plan" that includes a baseline measure of congestion and transportation emissions as well as a description of progress towards goals and projects to achieve those goals. These plans must be updated every 2 years.

Washington, DC used CMAQ funds (in part) to help launch Capital Bikeshare, providing a transportation option other than solo driving for short trips.

Transportation Infrastructure Financing and Innovation Act (TIFIA)

The TIFIA program provides loans, loan guarantees, and standby lines of credit to highway, bridge, transit, and intermodal freight projects that have a dedicated source of revenue pledged toward repayment.

TIFIA loans are an attractive financing option because 1) the government offers a lower interest rate than is typically available to project sponsors through traditional bond markets and 2) the repayment terms are flexible, including the ability to defer repayment so a project can get underway and/or begin generating user fees or other revenues before repayment begins.

With the passage of MAP-21, the TIFIA program changed in three major ways: first, the amount of money available for loans multiplied eight-fold; second, TIFIA projects will no longer be chosen through a competitive process, instead awarded on a first come, first served basis; and third, technical changes will make TIFIA financing more accessible for transit projects supported by sales, property, or income taxes.

Funding

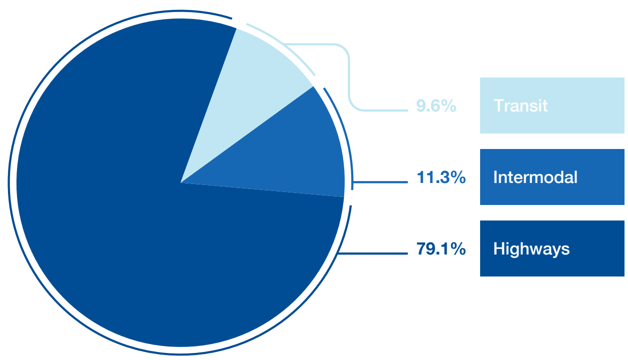
SAFETEA-LU	**MAP-21**
$122 million per year	**$750 million in FY13** **$1 billion in FY14**

The TIFIA program authorization is a form of credit subsidy. The actual direct loan comes from the Treasury Department. Every TIFIA program dollar can leverage approximately ten dollars in direct loans. Over the next two years of MAP-21, the TIFIA program will be able to support more than **$17 billion in direct loans to eligible surface transportation projects.**

Eligible projects

TIFIA may finance construction of highways, bridges, transit, intermodal freight facilities and projects related to intercity rail and bus service. Moreover, multiple projects may be bundled together under one loan application as long as they are to be repaid by a common revenue source.

Share of TIFIA Loans: 1998-2011
by Mode



In order to take advantage of TIFIA financing, project sponsors must have a reliable source of local revenue to pledge as repayment. For highway and bridge projects, this typically involves charging roadway users a toll. Transit projects are often supported by sales and property taxes.

How the program works

All TIFIA loans will now be provided on a first-come, first-served basis. If a project is eligible and meets the cost threshold below, a project sponsor will receive a TIFIA loan that can cover up to 49 percent of total project costs.[1] Moreover, USDOT may commit all $1.75 billion in TIFIA financing — including the entire second year of funding for FY14 — during the first year.

In order to be eligible to receive a loan, a project must have a total cost of more than $50 million or exceed 33 percent of what a state receives in federal highway dollars for a year. Project sponsors are permitted to bundle related projects together in order to meet that total cost threshold, provided they are all secured by a common repayment source.

1 For projects taking advantage of the modified springing lien provision, a TIFIA loan may not exceed 33 percent of total cost. In order to qualify for the modified springing lien provision, the project sponsor must be a public agency with a broad-based tax such as sales, property, or income.

The Crenshaw line in Los Angeles received a $545 million TIFIA loan for construction

In rural areas, project costs must exceed $25 million. Also, rural projects are eligible for a loan with an interest rate at half of the rate offered to projects in urban areas. (As of this writing, the current TIFIA rate is 2.97 percent. For rural projects, this would drop to 1.41 percent.) Intelligent transportation system (ITS) projects must exceed $15 million.

Prior to MAP-21, many transit projects were unable to compete for TIFIA financing due to technical provisions. MAP-21 includes important provisions that will allow transit projects supported by broad-based tax revenues such as sales and property taxes to more easily qualify for TIFIA loans.

Cap and Trade

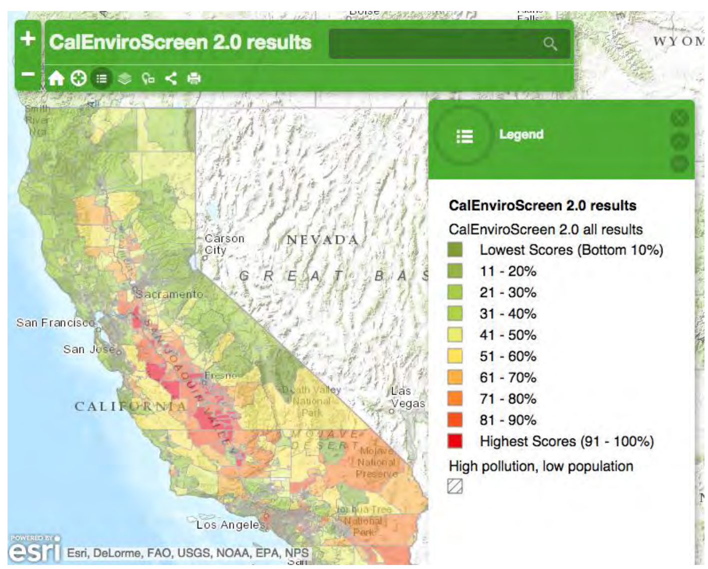
The California Global Warming Solutions Act of 2006, AB 32, is a multi-year program to reduce Greenhouse Gas (GHG) emissions in California to 1990 levels by 2020. One key strategy to achieve this goal is a ‘cap and trade’ market system. The ‘cap’ creates a limit on carbon dioxide equivalent emissions, while a corresponding number of allowances within the cap can be ‘traded.’ The allowances are purchased by utilities and businesses at quarterly auctions. Over time, as the cap lowers, businesses that aggressively reduce emissions can trade their surplus allowances to firms that find it more expensive to reduce emissions.

The auction proceeds are then used to further the goals of AB 32. Cap and trade auctions began in November 2012. The majority of auction proceeds are required by the California Public Utilities Commission (PUC) to benefit ratepayers of investor owned utilities. The smaller ‘state portion’ of auction proceeds is deposited into the Greenhouse Gas Reduction Fund (GGRF). GGRF investments are primarily targeted at clean transportation and sustainable community plans, corresponding with the impact transportation has on GHG emissions. Improvements to energy efficiency and natural resources management also contribute, but at lesser levels than transportation oriented factors.

The sale of cap and trade allowances generates substantial revenue—estimated at between $2 and $3 billion per year – which is dedicated to further reducing GHG emissions and achieving other co-benefits such as pollution reduction, public health improvements and economic growth. Revenue from cap and trade is allocated by the Legislature to a variety of programs many of which can be an important source of funding for local governments to achieve their sustainability goals. Approximately 60 percent of annual GGRF revenues have been “continuously appropriated” to a variety of state programs; the remaining 40 percent of revenues are subject to annual legislative appropriation through the state budget.

GHG and Disadvantaged Communities

All cap and trade funding programs are required to reduce GHG emissions. Additionally, SB 535 (de León, Chapter 830, Statutes of 2012) requires that 25 percent of all non-utility cap and trade revenues be used to benefit disadvantaged communities (DAC), and 10 percent to be spent within the most disadvantaged. Individual programs may exceed or be less than the 25% requirement for DACs, but on average the programs as a whole must meet the statewide requirement. The determination of DAC status is based on the CalEnviroScreen, a model administered by CalEPA that combines economic data with information on pollution and other environmental impacts.



Funding for Local Governments

The State of California's 2014-15 budget and the Governor's proposed 2015-16 budget include a variety of new and existing grant programs using AB 32 cap-and-trade auction revenues to fund local government sustainability efforts. While these funding programs are administered throughout various state agencies, the goal of the cap and trade program is to advance both the State's AB 32 GHG reduction goals as well as the goals in local Climate Action Plans and other sustainability programs and projects in communities.

Summary of Funding Programs

The 2014-15 State Budget provides $832 million in Cap and Trade proceeds to support existing and pilot programs that will reduce GHG emissions and meet SB 535 goals. This expenditure plan will reduce emissions by modernizing the state's rail system including high-speed rail and public transit, encouraging local communities to develop in a sustainable way with an emphasis on public transportation and affordable housing, increasing energy, water, and agricultural efficiency, restoring forests in both urban and rural settings and creating incentives for additional recycling. The budget permanently allocates 60 percent of future auction proceeds to public transit, affordable housing, sustainable communities and high-speed rail. The remaining proceeds will be annually allocated in future budgets. Funding for these programs is identified as either an "ongoing" or "one-time" appropriation in the description of each program. This brochure provides an overview of 13 funding streams – related to transportation, clean energy, and natural resources – that either directly or indirectly benefit cities and counties implementing local sustainability plans and goals, along with examples of the types of projects that could be funded in whole or part through the Greenhouse Gas Reduction Fund. Each program is administered by a different state agency. Please see the following page for a breakdown of the administering agencies.

More information can be found on ILG's Cap and Trade Resource Center at www.ca-ilg.org/cap-and-trade-resource-center.

TRANSPORTATION

$125M Housing and Community Development – Affordable Housing & Sustainable Communities

$230M California Air Resources Board – Low Carbon Transportation

$25M California State Transportation Agency – Transit & Intercity Rail Capital

$25M Caltrans – Low Carbon Transit Operations

$250M High Speed Rail Authority – High Speed Rail

ENERGY EFFICIENCY

$20M California Energy Commission – Energy Efficiency in Public Buildings

$75M California Department of Community Services and Development – Low-Income Weatherization/Renewable Energy

$25M California Department of Food and Agriculture – Agricultural Energy and Operational Efficiency ($10M from 2013-2014, $15M from 2014-2015)

$30M Department of Water Resources – Water Energy Efficiency (from 2013-2014)

NATURAL RESOURCES

$5M Department of Conservation – Sustainable Agriculture Land Conservation

$42M CalFire – Urban Forestry & Forest Health

$25M Department of Fish and Wildlife – Wetlands & Watershed Restoration

$25M CalRecycle – Waste Diversion

Affordable Housing and Sustainable Communities Program

PROGRAM AREA: TRANSPORTATION
FUNDING LEVEL: *20% ongoing allocation; $125 million in 2014-15 budget; 50% of funds must benefit disadvantaged communities.*
ADMINISTERING AGENCY: Housing and Community Development.
GHG methodology by CARB. Program guidelines by the Strategic Growth Council.

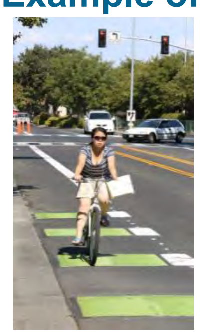
Program Description

This competitive program seeks to fund city and county projects that result in the reduction of greenhouse gas emissions (GHG) and vehicle miles travelled (VMT) and increase accessibility of housing, employment centers and key destinations through low-carbon transportation options such as walking, biking and transit. There are two eligible project types: 1) Transit-Oriented Developments combined with affordable housing units, and 2) Integrated Connectivity Projects that include active transportation/complete streets infrastructure combined with trip reduction programs or local planning/implementation. Program applications are due in April 2015 with funding awards in June 2015.

Successful Project Attributes

Based on the requirements and priority criteria of the program, the most successful city and county projects would be cost-effective transportation infrastructure/programs with multiple co-benefits that are already CEQA approved and “shovel-ready” to implement regional GHG reduction plans. Given the requirements for environmental clearances and emphasis on GHG reduction per dollar requested, most cities and counties would benefit from active transportation projects that combine infrastructure with trip reduction education due to minimal cost per ton for VMT and GHG reduction, minimal CEQA requirements, and maximum co-benefits such as improved health and air quality. Additionally, active transportation projects are an effective strategy to improve accessibly within and between communities of all kinds.

Example of Eligible Project: City of Davis Complete Streets Road Diet



The Davis City Council in 2009 endorsed a reconfiguration for Fifth Street, a major arterial that provides crosstown access to the downtown core and UC Davis. As part of the design phase, the city conducted a series of public workshops to gather community input. The redesign included changing the roadway from two vehicle lanes in each direction to one vehicle lane and a bike lane, plus turning lanes. The project also added marked crosswalks, more streetlights and Americans with Disabilities Act (ADA)-compliant ramps. In 2010 the city received a Sacramento Area Council of Governments (SACOG) Community Design Grant and in 2012, it received a Highway Safety Improvement Program Grant earmarked for pedestrian safety improvements. Construction began in fall 2013, and the final phase was completed in late 2014. It has become a widely used path of travel for cyclists and allows Fifth Street to tie in to the city’s extensive bike path and lane network while providing a much safer cycling route for people to get to and from the UC Davis campus and the active downtown.

Low Carbon Transportation

PROGRAM AREA: TRANSPORTATION
FUNDING LEVEL: *One-time allocation; $230 million in 2014-15 budget; At least 50% of funds must benefit disadvantaged communities*
ADMINISTERING AGENCY: California Air Resources Board (CARB)

Program Description

This program seeks to accelerate the transition to low carbon freight and passenger transportation, with a priority for disadvantaged communities. This investment will also support the statewide goal to deploy 1.5 million zero-emission vehicles in California by 2025. CARB administers existing programs that provide rebates for zero-emission cars and vouchers for hybrid and zero-emission trucks and buses. These expenditures will respond to increasing demand for these incentives, as well as provide incentives for the pre-commercial demonstration of advanced freight technology to move cargo in California, which will benefit communities near freight hubs. Additionally, cities and counties are eligible to apply for competitive grants in the following program categories. Funding levels and proposal solicitations will be out in spring 2015 with funding awards in June 2015:

- Freight demonstration projects -- $50M
- Light duty pilot projects in disadvantaged communities -- $9M
  - Targeted Car Sharing in Disadvantaged Communities – Up to $2.5M
  - Increased Incentives for Public Fleets in Disadvantaged Communities – Up to $3M
- Zero-emission truck and bus pilot projects in disadvantaged communities -- $25M
  - Zero-emission transit bus
  - Zero-emission school bus
  - Zero-emission freight/delivery truck

Successful Project Attributes

Cities and counties can take advantage of a few funding components within this program, including: rebates for public fleets located in or serving disadvantaged communities (up to $5,250 for plug-in hybrid electric vehicles), up to $10,000 for battery electric vehicles, and up to $15,000 for fuel cell electric vehicles. Additionally, local governments can benefit from other program categories that transit agencies, air districts, or local businesses may apply for, such as advanced technology demonstration projects, hybrid and zero-emission trucks and buses, and pilot programs such as electric car-sharing in disadvantaged communities.

Example of Eligible Project: SunLine Transit Agency Fuel Cell Buses

Transit became one of two early adopters of hydrogen fuel cell transit fleets in California. In April 2010 SunLine introduced the first advanced technology bus, the "New Flyer Fuel Cell," with a range of 250 to 300 miles. This bus has accumulated over 80,000 miles to date. In January 2012 SunLine introduced a second fuel cell bus, the "American Fuel Cell," with a range of 300 to 350 miles. This bus has accumulated over 75,000 miles to date. In June 2014 SunLine introduced its third fuel cell bus with the latest 8th generation hydrogen fueled vehicle technology with a range of 300 to 350 miles.

Transit & Intercity Rail Capital

PROGRAM AREA: TRANSPORTATION
FUNDING LEVEL: *10% ongoing allocation; $25 million in 2014-15 budget; 25% of funds must benefit disadvantaged communities.*
ADMINISTERING AGENCY: California State Transportation Agency developed guidelines, scores applications, and makes recommendations. Funding allocated and program administered by California Transportation Commission.

Program Description

This competitive grant program for rail and bus transit operators funds capital improvements that integrate state and local rail and other transit systems, including those located in disadvantaged communities, and those that provide connectivity to the high-speed rail system. The State Transportation Agency will prepare a list of projects recommended for funding, to be submitted to the California Transportation Commission for programming and allocation. Eligible projects include connectivity improvements to existing/future rail and transit systems, increased service and reliability of intercity and commuter rail and transit, rail integration of ticketing/scheduling systems, and bus rapid transit or other GHG reducing transit investments. Policy objectives for the program include reduction of greenhouse gas emissions, expansion and improvement to rail service to increase ridership, rail service integration of the state's various rail operators (including integration with the high-speed rail system), and improvements to rail safety. In addition to reducing GHG emissions, projects will be evaluated based on the implementation of regional Sustainable Communities Strategies and co-benefits such as improving public health, promoting active transportation, or reducing vehicle miles travelled. Program applications are due in April 2015 with funding awards in August 2015.

Successful Project Attributes

Eligible applicants include public agencies (including Joint Power Authorities) that operate existing or planned regularly scheduled intercity or commuter passenger rail service or urban rail transit service. An eligible applicant may partner with transit operators that do not operate rail service on projects to integrate ticketing and scheduling with bus or ferry service. This program will be competitive among eligible applicants and based on GHG reduction and other policy objectives. Cities and counties are encouraged to coordinate with their local transit providers to enhance system wide sustainability goals and look for ways to leverage other funding sources.

Example of Eligible Project: LA "Metro Rapid" Demonstration Program

The Metro Rapid Demonstration Program was implemented in June 2000, and now operates within a network of nearly 400 miles of Metro Rapid service, while integrating light and heavy rail transit through Los Angeles County. Buses now arrive as often as every 3-10 minutes during peak commute times, and include a number of key attributes such as bus signal priority, low-floor buses, and fewer stops. Passenger travel times have been reduced by as much as 29 percent. As a result, initial ridership increased by up to 40 percent, with one third of that ridership increase from new riders who had never used public transit.

Low Carbon Transit Operations

PROGRAM AREA: TRANSPORTATION
FUNDING LEVEL: *5% ongoing allocation; $25 million in 2014-15 budget; 50% of funds must benefit disadvantaged communities.*
ADMINISTERING AGENCY: Caltrans. GHG methodology by CARB.

Program Description

This formula-based program was created to provide operating and capital assistance for transit operators or regional transportation planning agencies to reduce greenhouse gas emissions and increase transit ridership, with a priority on serving disadvantaged communities. Eligible projects include new or expanded bus and rail services, as well as service or facility improvements such as equipment, fueling and maintenance. Expenditures are required to result in an increase in transit ridership and a decrease in GHG emissions. Transit projects must achieve GHG reductions by reducing passenger vehicle miles travelled through incentives, infrastructure, or operational improvements (e.g., providing better bus connections to intercity rail, encouraging people to shift from cars to mass transit). For agencies whose service area includes disadvantaged communities, at least 50 percent of the total funds received must be expended on projects that will benefit disadvantaged communities. Program applications are due in April 2015 with funding awards in June 2015.

Successful Project Attributes

Funding amounts will be distributed by formula to local transit operators, transportation planning agencies, county transportation commissions, or any other agencies that are eligible for State Transit Assistance funds. This program is not competitive and cities and counties are not eligible to apply directly, however, cities and counties may coordinate with their local transit providers to enhance system wide sustainability goals.

Example of Eligible Project: Riverside Transit Agency Offers Free Bus Passes to Students

The Riverside Transit Agency (RTA) has been recognized for its hugely successful student ride programs and involvement in public promotion of the transit system. RTA's Go-Pass and U-Pass programs have provided Riverside County college students free transit access for nearly a decade, with thousands of students getting unlimited rides on RTA buses by simply swiping their campus IDs. The program encompasses five partner schools: Cal Baptist, La Sierra University, Mt. San Jacinto College, Riverside City College and UC Riverside. The program is responsible for more than 1.5 million student boardings each year and credited not only for saving students money, but also reducing campus traffic and air pollution.

High Speed Rail

PROGRAM AREA: TRANSPORTATION
FUNDING LEVEL: *25% ongoing allocation; $250 million in 2014-15 budget*
ADMINISTERING AGENCY: California High Speed Rail Authority

Program Description

The Greenhouse Gas Reduction Fund includes an investment of $59M for further environmental planning, permitting, and design work for the first phase of the California High Speed Rail Project (which would extend from San Francisco to Anaheim) and $191 for right-of-way acquisition and construction of the initial operation segment in the Central Valley, which would extend 130 miles from Madera to Bakersfield. The State Budget also provides an ongoing commitment that allows for the advancement of the project on multiple segments concurrently, which yields cost savings and creates an opportunity for earlier potential private sector investment. These investments in the high-speed rail system will alleviate pressure on California’s current transportation network and will provide both environmental and economic benefits.

Successful Project Attributes

This funding is allocated directly to the High Speed Rail Authority to support the construction of the high-speed rail project. Local governments are not eligible for funding from this program, however, other cap and trade programs encourage or provide funding for connectivity and accessibility between local transportation systems and the statewide system (e.g. the Transit and Intercity Rail Capital Program includes funding for High Speed Rail connectivity).

Example of Related Project: Sacramento Intermodal Transportation Facility

The Sacramento Intermodal Transportation Facility (SITF) is a master-planned, multi-phased project, comprising separate but related facilities that, when complete, will enable state-of-the art operations for multiple modes of transportation at a unified site. It will provide user-friendly connections between all modes of transportation – train, light rail, bus, bicycle, pedestrian, taxi and automobile with future planning for California High Speed Rail into the site area. Phase 1 of the SITF was largely completed with the realigning of rail track infrastructure, separating freight and passenger tracks through the new passenger platforms with a new passenger tunnel and canopies with state-of-the-art information systems and ticketing. Construction began May 2011, and was completed in late 2013. The City of Sacramento secured $40 million in federal funds and $31 million in local and state funds for the construction of Phase 1. Major components of Phase 2 are to include architectural restoration and rehabilitation of the grand historic Sacramento Valley Station, that will be executed in guidance with the Secretary of the Interiors’ Standards for Historic Buildings. The City of Sacramento has been awarded a Federal Department of Transportation Investment Generating Economic Recovery (TIGER) IV grant for $15 million of federal funding to be matched with $15 million of local funding for the construction of Phase 2.

STATE OF CALIFORNIA
GOVERNOR'S OFFICE *of* PLANNING AND RESEARCH

EDMUND G. BROWN JR.
GOVERNOR

KEN ALEX
DIRECTOR

Preliminary Evaluation of Alternative Methods of Transportation Analysis

December 30, 2013

As required by statute, the Governor's Office of Planning and Research is developing a new way to measure environmental impacts related to transportation. This as an opportunity both to reduce costs associated with environmental review, and, importantly, to achieve better fiscal, health and environmental outcomes. We need your help in this effort.

I. Introduction

On September 27, 2013, Governor Brown signed Senate Bill 743 (Steinberg, 2013). Among other things, SB 743 creates a process to change analysis of transportation impacts under the California Environmental Quality Act (Public Resources Code section 21000 and following) (CEQA). Currently, environmental review of transportation impacts focuses on the delay that vehicles experience at intersections and on roadway segments. That delay is measured using a metric known as "level of service," or LOS. Mitigation for increased delay often involves increasing capacity (i.e. the width of a roadway or size of an intersection), which may increase auto use and emissions and discourage alternative forms of transportation. Under SB 743, the focus of transportation analysis will shift from driver delay to reduction of greenhouse gas emissions, creation of multimodal networks and promotion of a mix of land uses.

Specifically, SB 743 requires the Governor's Office of Planning and Research (OPR) to amend the CEQA Guidelines (Title 14 of the California Code of Regulations sections and following) to provide an alternative to LOS for evaluating transportation impacts. Particularly within areas served by transit, those alternative criteria must "promote the reduction of greenhouse gas emissions, the development of multimodal transportation networks, and a diversity of land uses." (New Public Resources Code Section 21099(b)(1).) Measurements of transportation impacts may include "vehicle miles traveled, vehicle miles traveled per capita, automobile trip generation rates, or automobile trips generated." (*Ibid*.) OPR also has discretion to develop alternative criteria for areas that are not served by transit, if appropriate. (*Id*. at subd. (c).)

Though a draft of the Guidelines revisions is not required until July 1, 2014, OPR is seeking early public input into its direction. This document provides background information on CEQA, the use of LOS in transportation analysis, and a summary of SB 743's requirements. Most importantly, it also contains OPR's preliminary evaluation of LOS and different alternatives to LOS. It ends with a description of open questions and next steps. In developing a better alternative to LOS, OPR will rely heavily on input from all stakeholders. We hope that you will share your thoughts and expertise in this effort.

Input may be submitted electronically to CEQA.Guidelines@ceres.ca.gov. Please include "LOS Alternatives" in the subject line. While electronic submission is preferred, suggestions may also be mailed or hand delivered to:

Christopher Calfee, Senior Counsel
Governor's Office of Planning and Research
1400 Tenth Street
Sacramento, CA 95814

Please submit all suggestions before **February 14, 2014** at **5:00 p.m**.

II. CEQA Background

Since SB 743 requires a change in the analysis of transportation impacts under CEQA, this section provides a brief overview of CEQA's requirements.

CEQA generally requires public agencies to inform decision makers and the public about the potential environmental impacts of proposed projects, and to reduce those environmental impacts to the extent feasible. The rules governing that environmental analysis are contained in the Public Resources Code, in the administrative regulations known as the CEQA Guidelines, and in cases interpreting both the statute and the CEQA Guidelines.

Many projects are exempt from CEQA. Typically, however, some form of environmental analysis must be prepared. If a project subject to CEQA will not cause any adverse environmental impacts, a public agency may adopt a brief document known as a Negative Declaration. If the project may cause adverse environmental impacts, the public agency must prepare a more detailed study called an Environmental Impact Report (EIR). An EIR contains in-depth studies of potential impacts, measures to reduce or avoid those impacts, and an analysis of alternatives to the project.

The key question in an environmental analysis is whether the project will cause adverse physical changes in the environment. CEQA defines the "environment" to mean "the *physical* conditions that exist within the area which will be affected by a proposed project, including land, air, water, minerals, flora, fauna, noise, or objects of historic or aesthetic significance." (Pub. Resources Code, § 21060.5 (emphasis added).) As this definition suggests, the focus of environmental review must be on physical changes in the environment. Generally, social and economic impacts are not considered as part of a CEQA analysis. (CEQA Guidelines, § 15131.)

Once an agency determines that an impact might cause a significant adverse change in the environment, it must consider feasible mitigation measures to lessen the impact. (Pub. Resources Code, § 21002.) Specifically, a lead agency may use its discretionary authority to change a project proposal to avoid or minimize significant effects. (CEQA Guidelines, § 15040(c).) The authority to mitigate must respect constitutional limitations, however. Mitigation measures must be related to a legitimate governmental interest, and must be "roughly proportional" to the magnitude of the project's impact. (CEQA Guidelines, § 15126.4(a)(4).)

III. Background on Measures of Automobile Delay

Many jurisdictions currently use "level of service" standards, volume to capacity ratios, and similar measures of automobile delay, to assess potential traffic impacts during a project's environmental review. Level of service, commonly known as LOS, is a measure of vehicle delay at intersections and on roadway segments, and is expressed with a letter grade ranging from A to F. LOS A represents free flowing traffic, while LOS F represents congested conditions. LOS standards are often found in local general plans and congestion management plans.

Traffic has long been a consideration in CEQA. (See, e.g., *Fullerton Joint Union High School Dist. v. State Bd. of Education* (1982) 32 Cal. 3d 779, 794 (school district's reorganization could potentially affect the environment by altering traffic patterns).) In 1990, the Legislature linked implementation of congestion management plans, including LOS requirements, with CEQA. (Gov. Code, § 65089(b)(4).) LOS has been an explicit part of CEQA analysis since at least the late 1990's, when the sample environmental checklist in the CEQA Guidelines asked whether a project would exceed LOS standards. (See former CEQA Guidelines, App. G. § XV; see also, *Sacramento Old City Assn. v. City Council* (1991) 229 Cal. App. 3d 1011, 1033 (addressing claims of an EIR's inadequacy related to level of service analysis).)

IV. Problems with using LOS in CEQA

Though, as explained above, LOS has been used in CEQA for many years, it has recently been criticized for working against modern state goals, such as emissions reduction, development of multimodal transportation networks, infill development, and even optimization of the roadway network for motor vehicles. The following are key problems with using LOS in CEQA:

LOS is difficult and expensive to calculate. LOS is calculated in several steps:

- First, the number of vehicle trips associated with a project must be estimated.
- Second, after estimating the number of vehicle trips generated by the project, an analysis requires assumptions about the path that those vehicles may take across the roadway network.
- Third, traffic levels must be estimated at points along the roadway network, as compared to traffic that might occur without the project.
- Fourth, microsimulation models are used to determine traffic outcomes of volume projections.

Thus, an analysis under LOS typically requires estimates of trip generation, estimates of trip distribution, conducting existing traffic counts at points along the network, and an analysis and comparison of traffic function at each point for future project and "no project" scenarios.

LOS is biased against "last in" development. Typical traffic analyses under CEQA compare future traffic volumes against LOS thresholds. A project that pushes LOS across the threshold triggers a significant impact. In already developed areas, existing traffic has already lowered LOS closer to the threshold. Because the LOS rating used to determine significance of the project's impact is determined by total traffic (existing traffic plus traffic added by the project), infill projects disproportionally trigger LOS thresholds compared to projects in less developed areas.

LOS scale of analysis is too small. LOS is calculated for individual intersections and roadway segments. As traffic generated by a project fans out from the project, it substantially affects a few nearby intersections and roadway segments, then affects more distant intersections and roadway segments by a smaller amount. LOS impacts are typically triggered only at the nearby intersections and roadway segments where the change is greatest. Projects in newly developed areas typically generate substantially more vehicle travel than infill projects,[1] but that traffic is more dispersed by the time it reaches congested areas with intersections and roadway segments operating near the thresholds. As a result, while outlying development may contribute a greater amount of total vehicle travel and cause widespread but small increases in congestion across the roadway network, it may not trigger LOS thresholds. Further, piecemeal efforts to optimize LOS at individual intersections and roadway segments may not optimize the roadway network as a whole. Focusing on increasing vehicle flow intersection-by-intersection or segment-by-segment frequently results in congested downstream bottlenecks, in some cases even worsening overall network congestion.[2]

LOS mitigation is itself problematic. Mitigation for LOS impacts typically involves reducing project size or adding motor vehicle capacity. Without affecting project demand, reducing the size of a project simply transfers development, and its associated traffic, elsewhere. When infill projects are reduced in size, development may be pushed to less transportation-efficient locations, which results in greater total travel. Meanwhile, adding motor vehicle capacity may induce additional vehicle travel, which negatively impacts the environment and human health.[3] It also negatively impacts other modes of transportation, lengthening pedestrian crossing distances, adding delay and risk to pedestrian travel, displacing bicycle and dedicated transit facilities, and adding delay and risk to those modes of travel.

LOS mischaracterizes transit, bicycle, and pedestrian improvements as detrimental to transportation. Tradeoffs frequently must be made between automobile convenience and the

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[1] For information on the relationship between infill and compact development, and vehicle travel and GHG emissions, see Growing Cooler, Evidence on Urban Development and Climate Change, September 2007.

[2] This phenomenon is called Braess' Paradox. For a description, see Braess, Dietrich. 1968, translated 2005. "On a Paradox of Traffic Planning." *Transportation Science, 39 (4), pp. 446-450. ISSN 0041-1655.* For prevalence, see Steinberg, Richard and Zangwill, Willard I. (1983) The prevalence of Braess' paradox. *Transportation science*, 17 (3). pp. 301-318. ISSN 0041-1655

[3] Duranton, Gilles, and Matthew A. Turner. 2011. "The Fundamental Law of Road Congestion: Evidence from US Cities." *American Economic Review*, 101(6): 2616-52.

provision of safe and efficient facilities for users of transit and active modes. Since LOS measures the delay of motor vehicles, any improvement for other modes that might inconvenience motorists is characterized as an impediment to transportation.

Use of LOS thresholds implies false precision. Calculating LOS involves a sequence of estimates, with each step using the output of the previous step. Imprecision in an early step can be amplified throughout the sequence. While it is difficult to estimate the distribution of future trips across the network with a high level of precision, the calculation of congestion levels is highly sensitive to that estimate. Further, LOS is typically reported in environmental analyses without acknowledging potential uncertainty or error.

As a measurement of delay, LOS measures motorist convenience, but not a physical impact to the environment. Other portions of an environmental analysis will account for vehicular emissions, noise and safety impacts.

V. SB 743

SB 743 marks a shift away from auto delay as a measure of environmental impact. It does so in several ways.

First, it allows cities and counties to designate "infill opportunity zones" within which level of service requirements from congestion management plans would no longer apply. (See, SB 743, § 4 (amending Gov. Code, § 65088.4).)

Second, it requires OPR to develop criteria for determining the significance of transportation impacts of projects within transit priority areas, and further provides OPR with discretion to develop such criteria outside of transit priority areas. The Secretary for the Natural Resources Agency must then adopt the new criteria in an update to the CEQA Guidelines. (See, SB 743, § 5 (adding Pub. Resources Code § 21099).)

Third, and perhaps most importantly, once the CEQA Guidelines containing the new criteria are certified, "automobile delay, as described solely by level of service or similar measures of vehicular capacity or traffic congestion shall not be considered a significant impact on the environment pursuant to this division, except in locations specifically identified in the guidelines, if any." (*Id*. at subd. (b)(2).)

SB 743 includes legislative intent to help guide the development of the new criteria for transportation impacts. For example, Section 1 of the bill states: "New methodologies under the California Environmental Quality Act are needed for evaluating transportation impacts that are better able to promote the state's goals of reducing greenhouse gas emissions and traffic-related air pollution, promoting the development of a multimodal transportation system, and providing clean, efficient access to destinations." Further, subdivision (b) of the new Section 21099 requires that the new criteria "promote the reduction of greenhouse gas emissions, the development of multimodal transportation networks, and a diversity of land uses." It also suggests several possible alternative measures of potential transportation impacts, including, but not limited to: "vehicle miles traveled, vehicle miles traveled per capita, automobile trip generation rates, or automobile trips generated."

Notably, SB 743 does not limit the types of projects to which the new transportation criteria would apply. Rather, it simply authorizes the development of criteria for the "transportation impacts of projects[.]" (New § 21099(b)(1); see also subd. (c)(1) (referring only to "transportation impacts").) The Legislature intended the new criteria to apply broadly. An early version of this provision, in SB 731, would have limited the new criteria to "transportation impacts for residential, mixed-use residential, or employment center projects [on] infill sites within transit priority areas." (See, SB 731 (Steinberg), amended in Assembly August 6, 2013.) Therefore, OPR will investigate criteria that would apply to all project types, including land use development, transportation projects, and other relevant project types.

An earlier version of SB 731 would have limited the application of these changes by determining that automobile delay is not an environmental impact only in transit priority areas. (See, SB 731(Steinberg), amended in Assembly September 9, 2013, at § 12 ("Upon certification of the guidelines by the Secretary of the Natural Resources Agency pursuant to this section, automobile delay, as described solely by level of service or similar measures of capacity or congestion within a transit priority area, shall not support a finding of significance") (emphasis added).) As adopted in SB 743, however, automobile delay may only be treated as an environmental impact "in locations specifically identified in the guidelines, if any." (New § 21099(b)(2).) Further, subdivision (c) explicitly authorizes OPR to develop criteria outside of transit priority areas. Given the statement of legislative intent that new transportation metrics are needed to better promote the state's goals, OPR intends to investigate metrics and criteria that will apply statewide.

VI. OPR Goals and Objectives in Developing Alternative Criteria

In developing alternative transportation criteria and metrics, OPR must choose metrics that "promote the reduction of greenhouse gas emissions, the development of multimodal transportation networks, and a diversity of land uses." (New Section 21099(b)(1).) In addition to this statutory directive, OPR will also weigh other factors in evaluating different criteria. Those additional factors include:

Environmental Effect. The California Supreme Court has directed that CEQA "be interpreted in such manner as to afford the fullest possible protection to the environment within the reasonable scope of the statutory language." (*Friends of Mammoth v. Board of Supervisors* (1972) 8 Cal. 3d 247, 259.) OPR, therefore, seeks to develop criteria that maximize environmental benefits, and minimize environmental harm.

Fiscal and Economic Effect. Our state and local governments have limited fiscal resources. The state's planning priorities are intended to, among other things, strengthen the economy. (Gov. Code, § 65041.1.) In evaluating alternative criteria, OPR seeks criteria that will lead to efficient use of limited fiscal resources, for example by reducing long run infrastructure maintenance costs, and to the extent relevant in the CEQA context, promotion of a stronger economy.

Equity. OPR will look for alternative criteria that treat people fairly. The state's planning priorities are intended to promote equity. (Gov. Code, § 65041.1.) OPR seeks to develop criteria that facilitate low-cost access to destinations. Further, OPR recognizes that in its update to the General Plan Guidelines, OPR must provide planning advice regarding "the equitable distribution of new public facilities and services that increase and enhance community quality of life throughout the community, given the fiscal and legal constraints that restrict the siting of these facilities." (Gov. Code, § 65040.12.) In addition, OPR must also provide advice on "promoting more livable communities by expanding opportunities for transit-oriented development so that residents minimize traffic and pollution impacts from traveling for purposes of work, shopping, schools, and recreation." (*Ibid*.) Though this advice must be developed within the General Plan Guidelines, OPR recognizes that similar issues may be relevant in the context of evaluating transportation impacts under CEQA.

Health. OPR recognizes that "[h]ealthy and sustainable communities are the cornerstones of the state's long-term goals." (Environmental Goals and Policy Report, Discussion Draft (September 2013), at p. 26.) OPR will, therefore, look for alternative criteria that promote the health benefits associated with active transportation and that minimize adverse health outcomes associated with vehicle emissions, collisions and noise.

Simplicity. The purpose of environmental analysis is to inform the public and decision-makers of the potential adverse effects of a project. (Pub. Resources Code, § 21003(b).) Environmental documents must "be written in plain language and may use appropriate graphics so that decision makers and the public can rapidly understand the documents." (CEQA Guidelines, § 15140.) OPR, therefore, seeks to develop criteria that are as simple and easy to understand as possible. The criteria should enable the public and other interested agencies to participate meaningfully in the environmental review process.

Consistency with Other State Policies. SB 743 included legislative intent that the alternative criteria support the state's efforts related to greenhouse gas reduction and the development of complete streets. OPR will also be guided by the state's planning priorities, and in particular, the promotion of infill development, as described in Government Code section 65041.1.

Access to destinations. Even as it serves and impacts many other interests, the fundamental purpose of the transportation network is to provide access to destinations for people and goods. A transportation network does this by providing mobility and supporting proximity. In growing communities, some degree of roadway congestion is inevitable[4]; we cannot "build our way out of congestion" by adding roadway capacity because doing so induces additional vehicle travel. Therefore, accommodating better proximity of land uses and improving the overall efficiency of network performance is essential for providing and preserving access to destinations. Transit and active mode transportation options can play a key role in providing access to destinations and supporting proximity.

The objectives described above need not be the only considerations in selecting alternative criteria. In fact, OPR invites your input into these objectives. *Are these the right objectives? Are there other objectives that should be considered?*

VII. Preliminary Evaluation of the Alternative Criteria

This section provides OPR's preliminary evaluation of the alternative metrics set forth in SB 743, as well as other metrics suggested during our initial outreach. This preliminary evaluation asks whether the alternative satisfies the objectives set forth in SB 743, as well as OPR's own objectives described above. It also attempts to identify which mitigation measures and project alternatives might flow from use of each candidate metric. Finally, this evaluation seeks to identify the level of difficulty of using each metric, including availability of models and data required.

Vehicle Miles Traveled

Variant 1: per capita for residential, per employee for employment centers, per trip for commercial
Variant 2: per person-trip for all projects

Vehicle Miles Traveled (VMT)[5] is one of two metrics specified by SB 743 for consideration. VMT counts the number of miles traveled by motor vehicles that are generated by or attracted to the project. VMT captures motorized trip generation rates, thereby accounting for the effects of project features and surrounds. It also captures trip length, and so can also account for regional location, which is the most important single determinant of vehicle travel. Although VMT counts only motor vehicle trips, not trips taken by other modes, it registers the benefits of transit and active transportation trips insofar as they reduce motor vehicle travel. In this way, VMT captures the environmental benefits of transit and active mode trips.

Of the metrics we consider here, VMT is relatively simple to calculate. Assessing VMT is substantially easier than assessing LOS because it does not require counting existing trips, estimating project trip distribution, or traffic microsimulation for determining congestion. Assessing VMT requires only estimates of trip generation rates and trip length, and can be readily modeled using existing tools such as the U.S. Environmental Protection Agency's EPA's MXD model.

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[4] Duranton, Gilles, and Matthew A. Turner. 2011. "The Fundamental Law of Road Congestion: Evidence from US Cities." *American Economic Review*, 101(6): 2616-52.

[5] For additional information about VMT and its relationship to environmental impacts, see U.S. Environmental Protection Agency, "Our Built and Natural Environments: A Technical Review of the Interactions Between Land Use, Transportation, and Environmental Quality (2nd Edition)," June 2013.

Mitigation to reduce VMT can include designing projects with a mix of uses, building transportation demand management (TDM) features into the project, locating the project in neighborhoods that have transit or active mode transportation opportunities, or contributing to the creation of such opportunities. Since VMT is sensitive to regional location, it can also be mitigated by choosing a more central location for the project.

Used as a transportation metric under CEQA, VMT could encourage reduction of motor vehicle travel, increase transit and active mode transportation, and increase infill development.

Automobile Trips Generated

Per capita for residential, per employee for employment centers

Automobile trips generated (ATG) is one of two metrics specified by SB 743 for consideration. ATG counts the number of motor vehicle trips that are generated by or attracted to the project. ATG thereby accounts for the effects of project features and project surroundings (i.e., the availability of transit). It does not, however, account for the length of the trip, and therefore it does not account for regional location, the most important determinant of vehicle travel[6]. Although ATG counts only motor vehicle trips, not trips taken by other modes, it registers the benefits of transit and active transportation trips insofar as they reduce motor vehicle trips taken. In this way, ATG captures some of the environmental benefits of transit and active mode trips.[7]

Of all the metrics considered, ATG is the easiest to calculate. It does not require counts of existing traffic, estimation of project trip distribution, or traffic microsimulation for determining congestion. In fact, calculating ATG is simply the first step in calculating most of the other metrics, including LOS.

Mitigation for ATG can include locating a project in an area that facilitates transit or active mode transportation, such as an infill or transit oriented location, and including transportation demand management features in the project.

Used as a transportation metric under CEQA, ATG could encourage reduction of motor vehicle travel, increased active mode transportation, and increased infill development. Because it omits regional location, however, it may be less effective at achieving those ends than VMT.

Multi-Modal Level of Service

Multi-Modal Level of Service (MMLOS) is a metric of user comfort for travelers on various modes. Along with the traditional motor vehicle LOS metric, MMLOS includes additional ratings for transit, walking

[6] Reid Ewing & Robert Cervero (2010) Travel and the Built Environment, Journal of the American Planning Association, 76:3, 265-294, DOI: 10.1080/01944361003766766.

[7] For more information on the ATG metric, see Automobile Trips Generated: CEQA Impact Measure & Mitigation Program, City of San Francisco, October 2008.

and biking modes. It rates intersections and roadway segments, delivering an A through F grade for each mode at each location. However, like LOS, MMLOS does not account for the total extent of motor vehicle travel, just its effect near the project. It also does not examine the transportation system on the scale of an entire trip length for other modes. The most commonly used MMLOS methodology is that put forth by the 2010 Highway Capacity Manual.

Assessing MMLOS requires detailed data on existing conditions for each mode of travel at intersections and roadway segments analyzed, plus trip generation and distribution by mode from the project. MMLOS is more difficult to calculate than LOS. Further, the methodology for non-motorized modes continues to develop. MMLOS is the subject of expert debate. For example, increased pedestrian traffic may be a desirable environmental outcome rather than an impact to be mitigated. Meanwhile, reducing the number of motor vehicle lanes on a street with bicycle lanes can benefit cyclists, but can degrade MMLOS under the Highway Capacity Manual's methodology.

Impacts determined by MMLOS can be mitigated by adding motor vehicle capacity, improving transit service, and/or adding amenities for transit and active mode travelers. Since transportation facilities near infill projects often already support a variety of modes, projects in these locations may require more mitigation than projects further from these amenities, potentially discouraging infill development.

MMLOS could act either to increase or reduce motor vehicle travel, depending on the relative weight of ratings between modes. It could encourage development of transit and active mode facilities, potentially increasing use of those modes. However, because it would assign the burden of those mitigations to development, it has the potential to raise infill costs and thereby reduce infill development.

Fuel Use

Per capita for residential, per employee for employment centers, per trip for commercial

Fuel use counts the amount of fuel used by vehicle trips generated by or attracted to the project. In doing so, it captures motorized trip generation rates, thereby accounting for the effects of project features and surrounds. It also captures trip length, and so can also account for regional location, which is the most important single determinant of vehicle travel. Finally, it also captures fuel efficiency, which is affected by vehicle mix and traffic conditions. Although fuel use counts only motor vehicle trips, not trips taken by other modes, it registers the benefits of trips taken by other modes insofar as they reduce motor vehicle travel. In this way, Fuel Use captures the environmental benefits of transit and active mode trips.

Assessing Fuel Use with precision would require the application of microsimulation tools over the area affected by project motorized vehicle traffic. Alternately, a fuel efficiency multiplier could be applied to VMT, but that would eliminate sensitivity to roadway operations, rendering this metric equivalent to the VMT metric.

Mitigation for Fuel Use can include building in transportation demand management (TDM) features as part of the project, locating the project in neighborhoods that supply transit or active mode transportation opportunities. Also, because Fuel Use traces the full extent of motor vehicle trips and therefore is sensitive to regional location, it can also be mitigated by choosing a more central location for the project. Mitigation measures for Fuel Use might also include improving motor vehicle traffic operations and speeds. However, to the extent that these mitigation measures would induce demand, they would lose effectiveness. In the coming years, fuel efficiency improvements will necessitate shifting thresholds, and zero emissions vehicles could eventually render the metric irrelevant. Also, permeation of electric-drive vehicles with regenerative braking reduces the effect of traffic operations improvements on fuel use.

Used as a transportation metric under CEQA, Fuel Use would act to reduce motor vehicle travel, except where transportation operations improvements or capacity expansions induce more travel in the long run. It would tend to increase transit and active mode transportation, although it could penalize their operation if they have a negative effect on motor vehicle traffic operations. Finally, it would tend to increase infill development, with the same caveats.

Motor Vehicle Hours Traveled

Per capita for residential, per employee for employment centers, per trip for commercial

Motor Vehicle Hours Traveled (VHT) counts the time taken by motor vehicle trips generated by or attracted to the project. In doing so, it captures motorized trip generation rates, thereby accounting for the effects of project features and project surroundings. It also captures trip length, and so can account for regional location, which is the most important single determinant of vehicle travel. Finally, it also captures travel time, which is affected by traffic conditions. Although VHT counts only motor vehicle trips, not trips taken by other modes, it registers the benefits of trips taken by other modes insofar as they reduce motor vehicle travel. In this way, VHT captures the environmental benefits of transit and active mode trips.

Assessing VHT with precision would require the application of more sophisticated modeling tools than those needed to assess VMT. In some areas, those tools may not be available or data might not be available to support them.

Mitigation for VHT can include building in transportation demand management (TDM) features as part of the project, locating the project in neighborhoods that supply transit, or active mode transportation opportunities. Because VHT traces the full extent of motor vehicle trips and therefore is sensitive to regional location, it can also be mitigated by choosing a more central location for the project. In the near term, VHT could be mitigated by increasing travel speeds, e.g. by increasing vehicle capacity. In the long run, however, increased travel speeds generate additional vehicle travel, eventually re-congesting the roadway and congesting traffic. Increased vehicle speeds may also adversely affect bicycle and pedestrian travel.

As a metric, VHT could act to reduce motor vehicle travel, except if it were used to justify roadway expansion to create short-run benefit without considering long-run induced demand. VHT would in many cases tend to increase transit and active mode transportation, although it would penalize their operation if they have a negative effect on traffic operations. Finally, in some cases VHT would remove a barrier to infill development, although mitigation measures that increase roadway capacity could have the opposite effect.

Presumption of Less Than Significant Transportation Impact Based on Location

Development in centrally-located areas and areas served by transit generally impacts the regional transportation network substantially less than outlying development. Given the lower motor vehicle trip generation rates and shorter trip distances that have been shown for projects in such areas compared with projects elsewhere, project location could serve as predetermined "transportation-beneficial development" areas. Such areas might be presumed to cause less than significant regional transportation impacts. These areas could be mapped so as to be easily identified. Projects outside of such areas may require additional analysis, and mitigation if necessary, using one of the metrics described above.

VIII. Open questions and next steps

The discussion above described OPR's initial impressions of several suggested transportation metrics. Many open questions remain at this point. Some of those open questions, as well as next steps, are set forth below.

1. SB 743 requires that whatever metric is developed, it must promote reductions in greenhouse gas emissions. Increases in roadway capacity for automobiles may lead to increases in noise, greenhouse gas emissions and other air pollutants. SB 743 similarly provides that air quality, noise, safety and other non-delay effects related to transportation will remain a part of a CEQA analysis.

    a. Are there environmental impacts related to transportation other than air quality (including greenhouse gas emissions), noise and safety? If so, what is the best measurement of such impacts that is not tied to capacity?

    b. Are there transportation-related air quality, noise and safety effects that would not already be addressed in other sections of an environmental analysis (i.e., the air quality section or noise section of an initial study or environmental impact report)? If so, what is the best measurement of such impacts that is not tied to capacity?

    c. Would consistency with roadway design guidelines normally indicate a less than significant safety impact?

2. What are the best available models and tools to measure transportation impacts using the metrics evaluated above? SB 743 allows OPR to establish criteria "for models used to analyze transportation impacts to ensure the models are accurate, reliable, and consistent with the intent of" SB 743. Should OPR establish criteria for models? If so, which criteria?

3. SB 743 provides that parking impacts of certain types of projects in certain locations shall not be considered significant impacts on the environment. Where that limitation does not apply, what role, if any, should parking play in the analysis of transportation impacts?

OPR will continue conducting research and meeting with stakeholders while this preliminary evaluation is being publicly reviewed. Following the close of the comment period, OPR will evaluate the input it receives, and develop a discussion draft of the alternatives to LOS and relevant changes to the CEQA Guidelines. The public will be invited to provide input on that discussion draft. If necessary, OPR may further revise the discussion draft based on that input. OPR intends to transmit a final draft of the changes to the CEQA Guidelines to the Natural Resources Agency by July 1, 2014.

RESOURCE PAPER

Transportation Data and Performance Measurement

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Transportation agencies have a wealth of data available related to the services they provide and the infrastructure they maintain. The challenge facing managers is to gather and analyze data in a way that provides timely information on whether they are consistently meeting their strategic goals. Whenever the goals are not being met, management must use information to identify changes. This paper describes how to develop a performance measures program; how to identify the customers and their needs; and how to identify, collect, and analyze the necessary data.

PROGRAM DEVELOPMENT

The development of performance measurement process takes place in four stages (Figure 1): identification of goals, development of performance measures, collection of data, and analysis and reporting of results. Although these stages imply a linear process (beginning with goal identification and ending with the reporting of results), transportation agencies should incorporate feedback loops between the stages as they design and implement their performance measurement systems.

In practice, each stage of the performance measurement process is accompanied by common problems. By understanding and anticipating these problems, transportation agencies should be able to move quickly toward a stable system that meets their needs.

Performance measures are an essential tool for focusing agencies on their strategic goals and ensuring continuous improvement. But of all the system performance measures an agency might develop, which ones are most important? Although a specific answer to this question will differ to some degree for each agency, several observations can be made. Performance measures should

- Address the concerns of three groups affected by the agency's vision and goals: customers, stakeholders, and employees. The interests of these three groups must be balanced in the measures selected. Management must avoid narrowly concentrating on measures of concern to only one group.
- Have relatively few measures so that attention is focused rather than scattered. Performance measures are often likened to the gauges of a dashboard. Several gauges are essential, but a vehicle with too many gauges is distracting to drive.
- Have a clear and definable relationship to the agency's goals. The best measures provide a direct link from business unit performance plans to the agency's vision. Measures that are indirectly related to the agency's vision and goals are less effective tools in managing the agency and improving performance.
- Obtain buy-in from customers, stakeholders, and employees. If these groups do not consider the measures appropriate, it will be impossible to use the results of the analysis process to report performance and negotiate the changes needed to improve it.
- Change slowly as the goals of the agency change in response to changes in the concerns of individual groups and as process improvements enhance performance in particular areas. In other words, once established, performance measures should be in place long

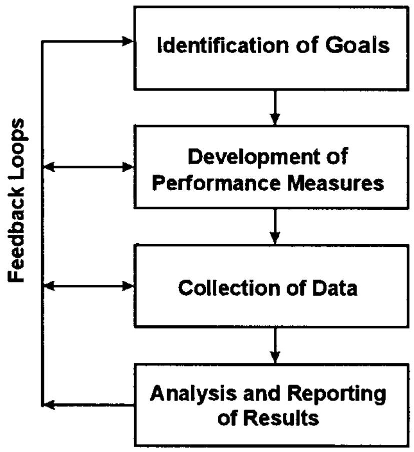


FIGURE 1 Four stages of performance measurement.

enough to provide consistent guidance in terms of improvements and monitoring to determine whether the objectives are being met.

- Facilitate improvement. If performance measures are not clearly for the purpose of improving the products and services of an agency, they will be seen as mere report cards and games will be played simply to get a good grade.

Reliable data, intelligently used and presented, are essential for the success of the type of measures described above. The availability and character of such data must be considered at each stage of a measure's development and use.

Identifying Goals

Long-range strategic goals must be translated into specific annual performance goals. A common goal for transportation agencies is to reduce highway congestion. Although this goal is easily stated, how should it be expressed? If the agency wants to achieve a 10 percent reduction in congestion over 10 years, how much of a reduction is reasonable to expect in any given year? Is the agency off track if it doesn't achieve a 1 percent reduction each year? Unless an agency has specifically developed a schedule of investments to address a uniform number of congested roadways each year, then it should expect its progress toward its goal to be uneven over time. In this case, the best short-term goal might be to forecast the expected improvement, given an approved multiyear program of projects, then measure whether the improvement was realized.

This example illustrates two points. First of all, goals must be reasonably attainable. The agency must have a plan for making them real. Simply stating "congestion should be reduced" without putting the resources in place and taking actions to make the reduction is an exercise in wishful thinking, guaranteed to frustrate people associated with the organization. Second, goals can be established either *prospectively,* whereby the goal is established and plans are put in place to achieve it, or *retrospectively,* whereby the plans are in place and the goals are derived from the existing plans (Figure 2). Although the prospective approach could better link plans to strategic goals, the retrospective approach tends to ensure that goals are attainable and realistic.

Another example related to internal process efficiency is a goal of having final designs available on schedule. In this case, the agency might take a snapshot of the design delivery schedule at the beginning of a year, then measure whether the schedule is met. As in the congestion example, the challenge will be in setting an appropriate target. A goal of designing 100 percent of the agency's plans to meet a fixed schedule is unrealistic given the environment in which designs are developed. Setting a goal at this level would simply frustrate design staff. It would be appropriate to do a benchmarking study to determine what percentage of projects are designed on time in a well-run agency. This percentage would be a reasonable long-term goal. If the current agency performance is well below this level, a series of short-term goals might be set rather than an objective than attempts to achieve too much in a short period.

These two examples demonstrate that performance measures are often complementary. Achieving the expected reduction in congestion each year depends on having the anticipated final designs complete so that the scheduled projects can be built. High performance for on-time design is critical to meeting the agency's goals for reducing congestion.

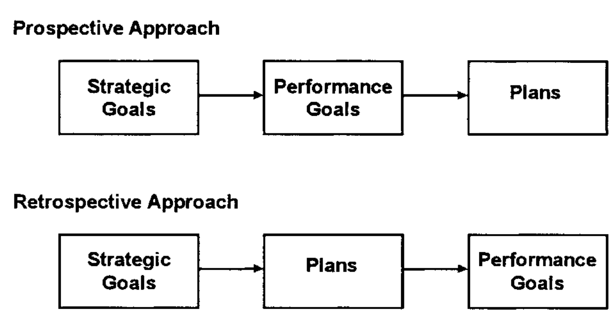


FIGURE 2 Alternative approaches for setting performance goals.

Developing Measures

Performance measures are often described as input, output, or outcome measures (Table 1). *Input measures* look at the resources dedicated to a program; *output measures* look at the products produced; and *outcome measures* look at the impact of the products on the goals of the agency.

Meaningful goals must go beyond a mere summary of program activities and define the outcomes of those activities, that is, whether performance is improved. Outcome measures are preferred because they directly relate the agency's strategic goals to the results of the activities undertaken to achieve them. Illustrating this issue and building on the congestion example given above, an agency with the goal of reducing congestion might measure the miles of capacity expansion it implements on congested highways during a given year. Miles of capacity expansion is a measure of activity or output in terms of system condition. A related outcome measure would be the change in the number of hours users spend in congested conditions.

Although outcome measures are generally preferred, transportation agencies need to consider data availability, cost, and validity when developing their system measures. The relationship between data collection and performance measure development is one of the critical feedback loops in the process of designing a performance measurement system.

Implementation of the outcome measure in the congestion example would require significantly more information than would implementing the output measure. An agency would need to know which congested highways were improved, and how congested they were; which congested highways were not improved, and how congested they were; how congestion translates into hours of delay; and how the highway improvements completed will reduce congestion. In deciding which measure to use, the agency would need to consider whether data can be collected to allow a measure to be calculated accurately and with sufficient frequency for it to be a useful tool in guiding agency decisions.

Hours of user delay may be a measure that captures customer concern, but measuring hours of delay in the field may be impossible. Even if it is technically possible to collect the data, limits might need to be placed on either the frequency with which the data are updated or the extent of the highway system covered. Such restrictions would limit the usefulness of the measure in evaluating agency performance. Another approach might be to estimate delay across the entire highway system using the *Highway Capacity Manual* procedures, but the uncertainty inherent in such estimates may negate their usefulness.

Another issue is to ensure that the measure selected is capable of capturing the impacts of the agency's activities given the underlying cause-and-effect processes. For example, another goal of most transportation agencies is to maintain pavement conditions at acceptable levels. A measure of pavement condition is, therefore, necessary. One measure an agency might select is the average pavement roughness or distress index. Would this be a good measure? Arguably, it would not for at least two reasons.

First, use of this measure implies that good pavements can offset bad pavements so long as average roughness does not increase. This explanation is at odds with the concept that highway users (the customers in this case) would prefer to minimize the number of bad miles of highway on which they must drive. Second, average roughness could increase even if the agency were successful in reducing the number of bad miles. The exact result would depend on how much the good pavements declined in average roughness, how much bad pavements improved, and what are the relative number of miles of each. Third, a decline in average roughness is appropriate for a pavement during its life cycle. The use of average roughness, then, could penalize an agency for doing the right thing. In this instance, the use of the number of bad miles would be a better measure because it relates to the cause of customer dissatisfaction.

Complexity and ease of understanding are also important to consider when developing performance measures. In the pavement example just discussed, one of the points made was that use of an average

TABLE 1 Types of Measures

Input	*Output*	*Outcome*
Dollars spent	Miles of pavement placed	Discernible improvement in pavement ride
Materials consumed	Miles of lanes added	People carried to jobs
Staff time consumed	Hours of bus service added	Reduced travel time

ignored the distribution of pavement conditions, that the issue was really the number of pavements toward the bad end of the scale. A statistician might suggest a skewness statistic as a method of measuring which way the distribution of pavement conditions is leaning. A decrease in the skewness coefficient from one period to the next would indicate that the distribution of conditions was moving toward lower (i.e., better) scores. Reporting a decrease in skewness to the public and to agency management, however, would not elicit the same level of understanding as reporting that the number of bad pavements decreased. The latter is a concept that can be easily understood, making it a very powerful measure.

Collecting Data

The examples presented in the previous section demonstrate that a direct relationship exists between the performance measures selected and the data needed in the performance measurement process. The most common data problems are in ascertaining the quality of the data and in acquiring it in the exact form desired.

The "garbage in, garbage out" concept applies to the data used in a performance measurement system. If the data gathered are highly uncertain, then the conclusions drawn by converting those data into performance measures also will be highly uncertain and will have reduced value in managing the agency. For this reason, great care needs to be taken in data collection. Investments in accurate, high-quality data-collection systems are essential to successful performance measurement and, by extension, to achieving the overall strategic goals of the agency. In reality, however, some things are important and either cannot be measured accurately or cannot be measured accurately at an acceptable cost. Transportation agencies need to consider the uncertainty introduced by inaccurate data when taking action based on their system of performance measures. More specific issues related to data collection and manipulation are discussed below.

Analyzing and Reporting Results

Once the desired data are in hand, the focus shifts to the analysis and reporting of results. In this stage, the most challenging problem is often separating the impact of the activities of the transportation agency from the impacts generated from beyond those activities. For example, highway crashes are influenced by many factors besides highway design. If an agency uses the total number of highway crashes as a performance measure, does an increase in crashes indicate that the agency's safety programs are ineffective? Before that conclusion is drawn, the impact of changes in the weather and other factors clearly needs to be understood.

The necessity of separating the impacts of external factors has direct implications for data collection, another of the important feedback loops in developing a performance measurement system. Even though statistical techniques might be available to allow the impacts of several factors to be isolated, the techniques require large numbers of observations to be used reliably. Thus, it is necessary to have a data-collection system that increases the number of observations by maintaining data with some degree of desegregation in both time and space. It also is necessary to gather data on relevant factors outside the agency's control. For example, if highway crashes are a performance measure and are influenced by severe weather conditions, then data need to be collected on severe weather across the agency's jurisdiction. It is also necessary to record crashes on an hourly or daily basis by location to determine how many occurred during periods of good versus bad weather.

Another aspect of the analysis of performance measures with a direct impact on data collection is the frequency with which the analysis is needed. The time period covered by an agency's goals and the time period for which current data are maintained must be consistent. In determining frequency, the agency should consider the nature of the processes underlying its activities. Consider pavement roughness, for example. Highway construction takes place over several months, and the schedule of work over the course of the year varies for many reasons. In this case, it would be of little use to measure, analyze, and report changes in pavement conditions less than annually. Poorer conditions early in the year do not necessarily imply the agency will end up with poorer conditions after all construction work is complete. In other cases, the underlying process may be much shorter than the frequency of analysis and reporting. If the process can be redirected on short notice, it may be useful to monitor the results of the ongoing process so that midterm corrections can be made if it appears that the agency's goal might not be reached.

As mentioned in the discussion of data collection, performance analysis results are often uncertain because data are difficult to collect accurately. This uncertainty often can be addressed in the analysis phase. One approach is to desegregate the performance data and determine whether all levels of aggregation perform similarly. This might be done by looking at conditions in varying geographical areas within the jurisdiction of the agency. If all areas perform similarly, the result conveys more certainty. If only one or two areas have poor results, then additional analysis can focus on those areas to determine whether there is reason to believe data accuracy issues are causing them to stand apart. Another approach is to look at related measures, which the underlying process suggests should be correlated with performance in areas prone to inaccurate data. If each measure points in the same direction, then the agency can be more confident of the results.

Analysis of performance also should consider combining feedback and performance data for a more complete picture. Data on changes in miles of bad pavement, for example, could be combined with customer feedback gained through pavement satisfaction surveys. One result can help verify and explain the other, and when results vary, it can point to the need to reevaluate the measures used.

Finally, analysis must consider the impact that the measures have on each other. Three goals have already been suggested for a highway organization: smooth pavement, reduced congestion, and fewer crashes. Success in increasing the smoothness of pavements may encourage higher speeds, which will increase crashes. A heavy commitment of resources to capacity projects may reduce resources available to pavement renewal or to safety improvements. An analytic process must be sufficiently complex to allow the policy choices to be highlighted and the relative impact of each to be understood. If competing goals cannot be analyzed, the results achieved will be haphazard.

Managers of highway systems are not alone in facing such challenges. Transit operators usually are forced to balance the need for efficiency with the need to provide mobility for people in low-density areas. Efficiency measures would tend to lead the operator to discontinue less-used routes. However, the demands for access to jobs in less-dense suburban locations might lead the operator to add more such routes. Policy makers and managers must be able to understand the interaction of these two goals that may be polar opposites in terms of their implementation. If policy makers determine greater mobility to be the primary goal, they must either accept a reduced emphasis on efficiency or adopt a system of performance measurement that is sufficiently complex to differentiate the efficiency of various types of services or routes.

Both of these examples of competing goals require reasonably sophisticated analytic processes that allow for various policy options to be considered in iterations, so that the interplay of those options can be understood.

Accepting Performance Measures

As transportation agencies move through the stages of the performance measurement process, it is important for them to keep in mind that a system will fail unless it has buy-in from customers, stakeholders, and employees. Agencies should view the development of a performance measurement system as an art, not a science. If performance measurement were a science, there would be one best way to do it. There is not. Given that performance measurement is an art, an agency's top managers must view themselves as artists who find creative ways to bring the brush strokes of all interest groups into a coherent form. Top management needs to set the agency's strategic direction and goals as well as broaden involvement in developing the performance measures that the agency uses. If done successfully, each group will believe in the results and be willing to act on them to achieve real improvement.

To ensure buy-in, an agency must consider not only what it does but also how it is done. Many of the points made in discussing the performance measurement process bear repeating because ignoring them will hurt the buy-in process. First, management must keep the measures few and simple. Second, management needs to ensure that the measures are directly related to agency strategic goals and directly influenced by agency activities. Third, performance measures must be developed and used as tools for improving critical processes, not as report cards. Finally, management must invest staff and resources in reliable data-collection systems and in the analytic methods required for timely analysis and reporting of results. A significant breakdown on any of these points will lessen the effectiveness of the performance measurement process and reduce the ability of the agency to successfully accomplish true process improvements.

Customer Identification

The earlier discussion focuses largely on measures that come from a transportation agency's standard data systems. Pavement quality, congestion, and crashes can be reduced to hard numbers and are routinely reported in most agencies. These are the traditional transportation measures. Customer measures provide another view of many of these traditional measures; they may provide a subjective overall as-

TABLE 2 Traditional and Customer Measures

Traditional Measures	*Customer Measures*
Quantitative measures	Qualitative measures
Routinely collected	Capture perceptions
Define condition or use of facility or service	Define priorities
One measure for each feature	Define how much is important
	May result in conflicting answers

sessment of quality, help to assign a priority to various issues, or help define how much of a given item is important (Table 2).

Customer measures are an important component in an organization's family of measures. They differ from traditional measures in that they are based on people's perceptions of the products and services delivered to them. Because no two people are the same, perceptions of the same thing can vary widely. Also, one person's perceptions about something can change from one point in time to another. This is quite different from traditional measurements. Fortunately, valid and reliable methods for measuring customers' perceptions allow organizations to use this valuable information to improve performance.

Who Is the Customer?

When an organization is using customer measures to help define its performance successes and improvement needs, a clear understanding of its customers is vital. A customer can be defined simply as the user or recipient of a product or service. Because there is likely to be more than one user of a given product or service, users are often referred to as *customer groups*. It is important to look for similarities in and differences between customer groups because they will affect the findings.

As the number of customers in a customer group increases, more and more differences between individuals in the group become evident, resulting in even more distinct customer groups or subgroups. Thus, a transportation agency with many products and services could have many customer groups, each of which has different needs, expectations, and perceptions.

In agencies with many products and services and a wide range of customers, different customers probably have competing or even opposing needs. How does an organization determine which action to take when two customer groups have opposite opinions of the service they have received? It might be possible to accommodate both groups, but if not, what then? As discussed above, the understanding of the differences between the customers and customer groups and having a clearly defined purpose will greatly help in the making of this determination. Also, factors such as resource capacity and economies of scale will affect the actions the organization can take. It is important to point out here that all customers are not created equal. Some key customers may be frequent users of the highway system (commuters); others may be large-volume users (truckers); others may be important because they have political or some other type of influence. Key customer groups should always be measured for their needs, expectations, and levels of satisfaction.

In many organizations, simply defining the customer can be a challenge. For instance, when a state trooper stops a motorist for speeding in a construction zone, who is the customer—the stopped motorist, the construction workers, the residents nearby, other drivers, the taxpayers, or the legislature? The answer could be any or all of these. It depends on how the agency defines what is being provided and what the goals are. The agency must clearly understand what is provided, how it fits into the overall objective, and why it should be measured before a performance measure can be developed with customer input.

How Does the Customer Relate to the Measure?

A *customer* is a user of the system or someone who benefits from the system. A *product,* then, can be defined as anything you provide to a person or group of people. Using this definition, a product can be one of two types: a tangible, visible thing, such as a license plate or a highway interchange, or an intangible thing, such as information about traffic laws in a construction zone or an analysis of how legislation affecting commercial trucking affects highway use. In the construction zone example, if the product is the state trooper's speeding ticket, then the customer is the driver, and the desired outcome is the driver's altered behavior when driving through work zones in the future. If the product is work zone safety, then the customer is the construction worker, and the desired outcome is a safer workplace.

Another aspect to providing a customer with a product is the experience itself. This is the interaction between the provider and the customer before, during, and after delivery of the product. The common phrase used to describe this aspect is *customer service*. A customer's perceptions of the experience (i.e., of obtaining and using a product) are as important as their perceptions of the product itself.

When one is measuring products, the intent is to determine the customers' perceptions of the attributes of the products themselves. When one is measuring the experience, the focus is on customers' perceptions of the people they deal with, their attitudes, professionalism, willingness to listen, knowledge of the product, understanding of the customers' concerns, and other characteristics. As an organization determines what to measure, keeping these differences in perspective will help determine the role that customer input should have in your primary system performance measures.

What Is Needed from the Customer?

What are you measuring and why? Before you start to develop your questions for customers, determine and be able to explain specifically what you hope to accomplish with the information you obtain. This knowledge will keep you focused as you develop and work through the process of developing a questionnaire, survey, or other customer-input device. If the purpose is unclear, inadequately developed, or not specifically related to the corporate measure, you will struggle to come up with questions that truly address the concerns that matter the most to your performance measure.

Consider the following questions as you begin to develop customer measures of performance:

- What is the primary issue or problem that we want to address?
- What will the results help us do differently?
- How would this information aid in the decision-making process?
- What specific actions do we intend to take after we have the results?
- Why do we need this information now?

As with all performance measures, differentiate output measures from outcome measures. Also if your product requires you to take something from a customer and work on transforming it into something else before you give it back, be sure to consider input measures.

Output measures are evident as soon as you have delivered the product. Outcome measures might not be evident until months after product delivery. Although output measures are usually easy to define, developing good outcome measures can be difficult. Outcomes in organizations often can be attributed to several different activities. It can be challenging to determine what portion of a customer's outcome is based on your product and what portion is based on products the customer received from other providers.

One potential risk that must be considered as you analyze your information needs is that your customers may not be familiar with your product or service. For example, consider the public's perception of pavement condition. If people are unaware of the department's policy or are aware of it but cannot relate to the engineering jargon nor understand the cost of different improvements, then it will be difficult for them to respond to questions about the policy. In these cases, separate questions may be needed to determine customers' awareness and understanding of the policy before determining satisfaction and using it to influence investment decisions.

Customer information is critical to any complete performance measurement system, but getting informed input from customers can be difficult. It must be done deliberately and with an understanding of the customers themselves.

Data Identification and Use

Collecting the right data depends on understanding what is to be measured, why it is being measured, and who will use the data.

What to Measure

Data often are collected for a performance measure without truly understanding what is to be measured. For example, many agencies have annual goals for improving pavement ride. To measure this goal, the agency might measure the number of miles that fall below an established ride standard (i.e., the number of "bad" miles). However, if resources were dedicated to meeting this goal and a program was implemented that should have met the goal but the goal remained out of reach, would the single program level measure be useful? In this case, the simple measure might not be useful because it would not allow the situation to be well understood.

To understand the issues, data and measures would be required at several levels. Some of the questions for which data and goals would be required include the following:

- Are pavements performing in the manner expected by the pavement management systems?
- If pavements are not performing as expected, is the problem with all pavements or with a particular pavement type?
- If asphalt pavements are not performing to standard, is the problem in a particular type of mix?
- If it is a specific mix, is the problem in materials, construction, base, or other factors?

These questions suggest a hierarchy of measures (Table 3), all of which are needed to understand the program.

Obviously, not all of these measures need to be or should be reported generally. Policy makers in a legislature or governor's office will probably be interested in only the highest level measurement. In addition, the highest level of agency management will probably have limited interests. Lower-level managers and technical staff will want and need to know the details that underlie the global measure.

Even this short hierarchy suggests a complex system. Although it is complex, it is not new to most highway agencies. Most agencies have some type of pavement management system. Such systems contain many assumptions about performance at different levels of detail that are effectively performance measures. Similarly, many design standards contain performance assumptions that can be used as performance measures. If they are understood to be measures and are used to better understand an issue, they can help to improve agency performance. Moreover, they can be used without creating complex new systems and, probably, without collecting significant new data.

Defining and Standardizing Data

For data to be used with confidence, they must be consistently defined. Standardization strives to define data to a degree that minimizes subjectivity and maximizes objectivity with respect to establishing a data item to promote accuracy and repeatability. Standardized data also are necessary for successful data integration. For example, how much has an agency spent on a given program? This is a frequently asked question, a question for which there can be many answers that are different but all correct. An accountant probably would answer in terms of dollars that have left the agency, on an expenditure basis. A federal program manager would probably answer in terms of the dollars moved to federal agreement, on an obligation basis. A program manager might answer with the amount contracted, on an encumbrance basis. Within their limits, all of the answers are correct, but they are different. If such information is reported as a part of a performance management system, the agency must determine which answer is most relevant to the audience and standardize this basis for answering. Another simple example, determining the length of a highway ramp, illustrates the point in the physical inventory world (Figure 3). Where does the ramp start and end? There is no right answer, but the answer must be consistent.

To standardize data, the data element in question must be understood. Data modeling efforts that include users or potential users of common data may prove useful for establishing and defining data to a detail that facilitates standardization.

Quality control is also necessary to standardize and use data with assurance. The Wisconsin Department of Transportation (WisDOT) recently implemented a quality control data-collection audit of its state highway inventory data. The audit focuses on sampling a percentage of the annual data updates. The results of the first year's audit have already generated benefits. The audit highlighted some key areas where inconsistencies were present in the collected

TABLE 3 Hierarchy of Pavement Performance Measures

Measure	*Use*	*Audience*
Number of bad miles	Overall pavement performance	Policy makers
Performance of pavement type	Measure overall performance	System managers
Performance of specific pavement designs	Measure performance within pavement type	System managers
Performance of specific pavement design components	Measure performance of pavement components	System managers, engineers, contractors

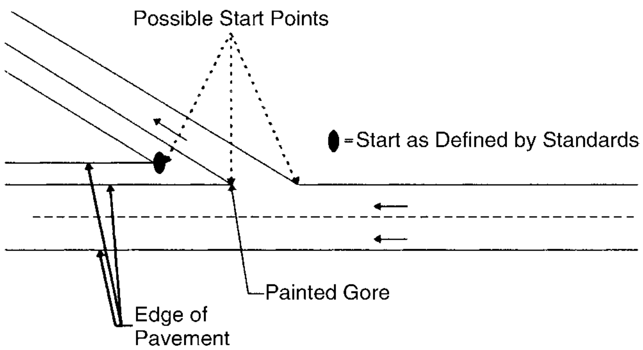


FIGURE 3 Location of ramp along mainline.

data. A follow-up to the audit will occur soon with all data collectors to review what was learned and to incorporate the findings into a revised data-collection manual.

Data Life

Data collection is usually expensive. Therefore, it is important to understand the useful life of data so that it can be leveraged as much as possible before an update is necessary. To determine the data's useful life, the data's accuracy necessary to address business requirements must be determined.

The useful life of data can be derived from the responsible use of the data. For example, highly detailed pavement condition ratings can be used to predict pavement condition for 5 to 6 years from the date of inspection. This means that one can confidently, or responsibly, generate a 5- to 6-year improvement program based on the data. It is tempting to generate long-term [or out-year (6+ years)] improvement programs because pavement deterioration curves can forecast conditions for up to 40 years. Although this forecast is possible mathematically, a responsible user will seek to understand the variables affecting data quality over time; this understanding should be used as the basis for determining the frequency with which to update and use data.

In contrast, some data have a long, useful life. Pavement width, shoulder width, pavement type, intersection location, and median location and type remain the same from the time they are built until reconstruction, so it is not necessary to plan a cyclical collection of such data. It also may not be necessary to collect the data in the field but to use its built plans or a photolog in the office to collect the data.

It is also wise to prioritize the importance of each data item. Although pavement and shoulder width remains static between construction times, it is important to have the current pavement and shoulder widths for doing capacity analysis. Therefore, collecting basic inventory data for new construction might be the highest priority. Collecting new construction data could be more important than collecting pavement roughness data, which changes slowly enough that delaying collection for several months would not affect system-level analysis.

Automatic or Manual Collection

Automation of data collection usually enables data to be collected quickly and efficiently. If the automation equipment is cost-effective and the data can be processed efficiently, then automation is likely to be a viable alternative to manual data collection. However, automated collection methods are not always the best way to collect data. Automation can work well if a large volume of data is collected daily (e.g., automatic traffic count and classification stations) or thousands of miles of road per year are rated (e.g., collecting pavement roughness). However, for data that is stagnant, such as political boundaries, manual collection may be more economical.

Automated data collection usually implies speed and efficiency, but the real value of automation is realized when speed is coupled with increased accuracy, precision, and repeatability of the data. The drawbacks of automated data collection typically relate to significant up-front capital costs and ongoing maintenance costs for equipment.

Defining the benefits of accuracy and precision for data items is a good starting point for the evaluation of automation benefits. Some data items do not lend themselves to accurate, precise, and efficient manual measurement; for example, it is almost impossible to obtain pavement roughness data and standardized, repeatable manual determinations of pavement roughness. Thus, automation is clearly a superior alternative. But for many data items, automation is not so easily distinguished as a superior data-collection method; in fact, automation might not be the best approach. The cost of equipment must be weighed against the benefits of enhanced accuracy, speed, and repeatability when an automated data-collection solution is considered (Figures 4 and 5).

Data may be collected through a combination of both manual and automated processes. Handheld devices that allow collectors to input and store data and then easily upload into a larger inventory system can contribute significantly to consistency and repeatability (Figure 6). Laptops and data boards provide much of the same functionality in other applications.

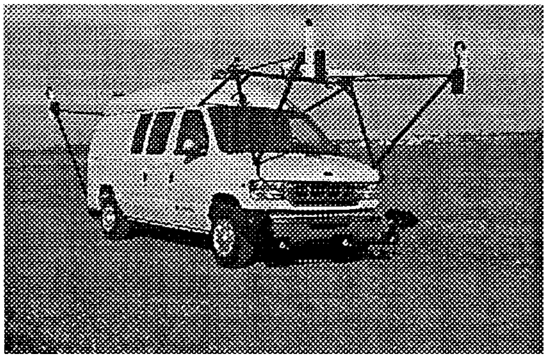


FIGURE 4 Automated pavement distress van.

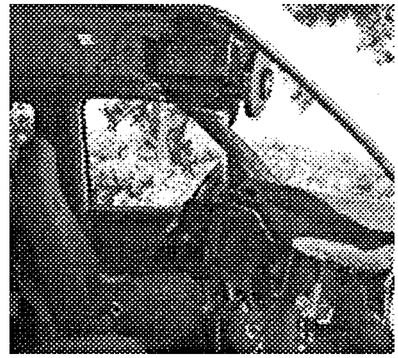


FIGURE 5 Photolog camera.

Location Control

One of the biggest challenges in collecting data with fully automated equipment is to ensure that the location control strategies are compatible. Geographic information system (GIS) technology may provide the location control basis to collect large volumes of data that are compatible with other inventory items. Without the ability to combine data, no matter how it is collected, the primary objective of using the needed data as an input into a performance analysis is lost.

For segment-based location referencing systems, physical inventory data are typically averaged to represent the overall segment. For many applications, this method works well, but there may be a need to establish the location of data more precisely. *On/at methodology* [a linear referencing (location control) system that allows a location address to be given to data] or a similar system allows data items to be located exactly as they exist without the need to average the data for attachment to a segment-based location. For example, a road segment varies in width along its length. On/at methodology allows width data to be located as it exists by attaching the location to each data item rather than forcing the data item to the location of a previously defined segment. Instead of one width attached to a segment, multiple widths can exist, representing actual occurrences.

An on/at method was determined to be the most logical for WisDOT's local roadway database (Figure

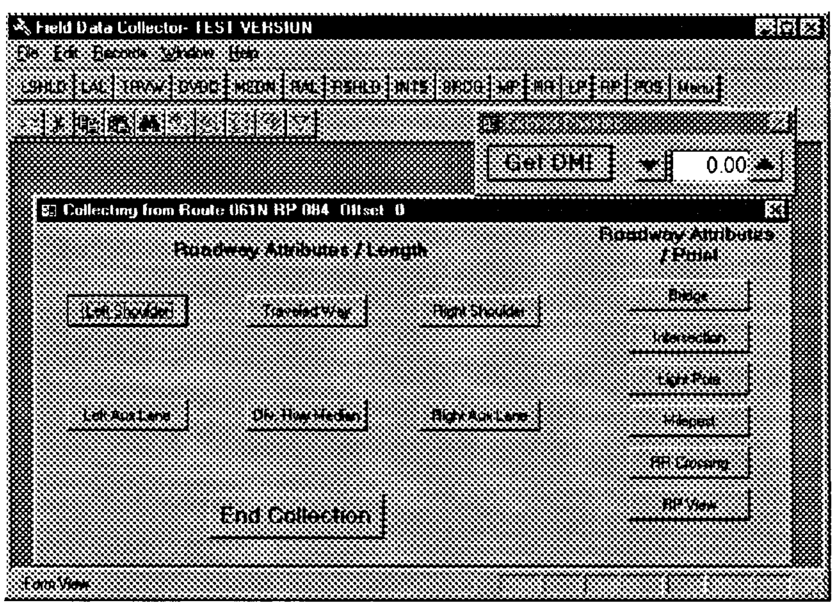


FIGURE 6 Automated field data-collection window.

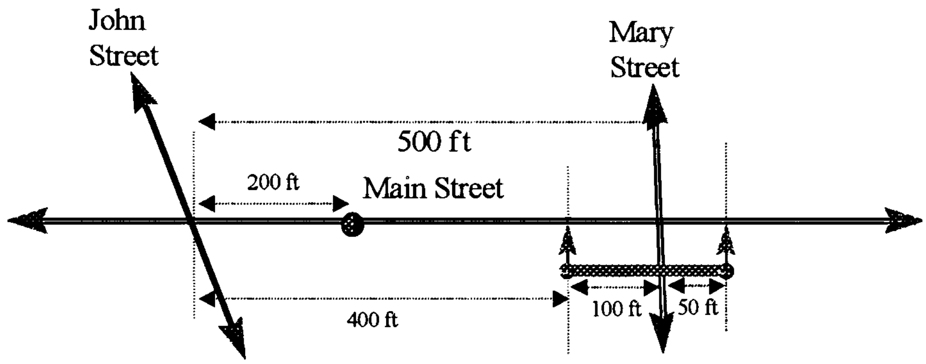


FIGURE 7 On/at location control system.

7). This method uses distance and direction on a road from an at-grade intersection. It can be used for identifying data that are at a point (e.g., bridges, railroad crossings, light poles, or intersections) or that have length (e.g., pavement types, roadway widths). For example,

- On Main Street, 200 ft past the intersection with John Street, traveling toward Mary Street (point).
- On Main Street, 400 ft past the intersection with John Street, continuing to 50 ft beyond the intersection with Mary Street (length).

Integration of Data

Data integration is a popular topic among users of data. A truly integrated database avoids the redundancy in the collection and storage of data common to independent databases. Integration also provides the user with more efficient access to data. Integration is nothing more than the ability to bring together data from various data storage systems effectively in an analysis. For this to happen, the data definitions and the location control systems must be compatible.

Data must have a common definition if they are to be integrated. The common definition is an often-overlooked problem when combining data for analysis. Simple problems such as collecting the data in English units versus metric units can be overcome by building conversion tables. But more complicated issues may hinder or even prohibit the combination of data. For example, if some critical data are collected or analyzed as an average over a segment, whereas other data are collected in extreme detail, rules for combining the data must be developed.

Location control is often an issue in integrating data. Data can be located by reference point systems, milepost markers, coordinate systems, and other ways (Figure 8). If various systems are in use and a translation program is not available, data will not be compatible.

The issue of location control compatibility is a challenge, especially within the context of a large or-

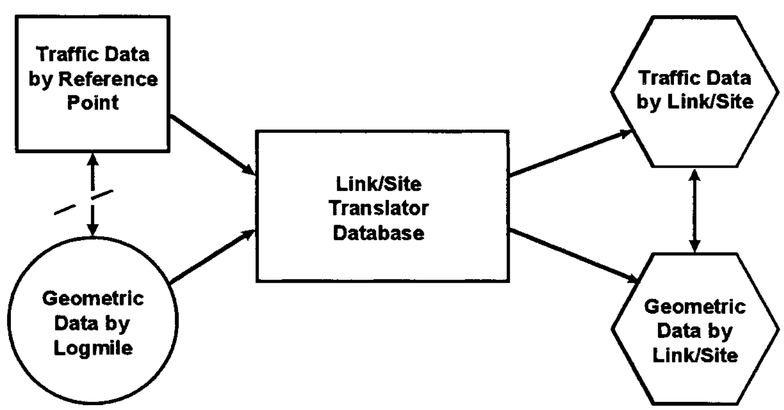


FIGURE 8 Link and site database, allowing integration of different location control systems.

ganization. In this environment, separate departments or units commonly use independent databases with independent location control systems that contain similar data. When data integration is proposed in such organizations, an associated requirement is that there must be a standard way of defining, locating, and managing data. A call for change is often met with great resistance. Units have strong reasons for resisting change. They own a particular data item, and that item is fully functional for their needs, so why should they change their business approach in light of the ever-present resource and budget constraints to satisfy someone else's desire for their data? With such parochial attitudes, data integration is often difficult.

If an organization has a strong mandate for integration or if standardized data definitions and methodologies are in place, then the barriers can be more readily removed. However, it is never inexpensive to convert data systems. Changing the database itself is usually the easiest part of the project. Identifying and converting all the programs or processes that use the legacy data system is the more expensive and time-consuming phase.

Sharing of Data

One unique aspect of data integration is data sharing across levels of government or agency lines. For example, good business practices and federal guidance encourage cooperation among state, metropolitan, and local planning agencies. In most cases, the data required to complete a reasonable planning effort, which should include elements of performance measurement, are common to all three levels of government. In many cases, each level of government maintains data systems that are tailored to its particular needs, which may include specific ways of rating pavement quality, individualized data definitions, or singular location control strategies. It also may include incompatible hardware and software installations. For example, many local governments in Wisconsin have some GIS capabilities, most of which were acquired with assistance from state land information programs. Most are incompatible with WisDOT GIS applications. In some cases, the differences lie in the software and hardware; in others, with location control strategies; and in still others, with the level of detail in the location systems. With all of these differences, how can plans and performance measures be reasonably coordinated? Unfortunately, the answer is usually through a manual comparison of output and the application of professional judgment.

A similar circumstance exists between agencies. For example, natural resources information often resides with the state resource agency. On the surface, geographically located and displayed information on wetlands, endangered species habitat, or agricultural lands might seem to be ideally suited to the analytical needs of the transportation agency. Are the resource agency's system and data compatible? Is the detail adequate for project- or even program-level analysis? In Wisconsin and many other states, the answer is usually no to at least one of the concerns.

These common interagency issues can be overcome only by great and continuing effort. Producers and keepers of data must be sensitive to the needs of other potential users. They must also understand the benefits of sharing information with all the involved agencies. Once that sensitivity and understanding exists, the producers and keepers will have a motivation to find solutions. Until it does, cross-agency sharing will remain a major challenge.

Data Access

At first it would appear that accessing data within a single agency would present little or no problem. The truth is the opposite. Access capabilities usually are not the same across large organizations, especially organizations such as state transportation agencies. State departments of transportation usually have several district offices and a headquarters office at remote locations. Each of these locations could have different computer capabilities. Some may not have desktop workstations that can handle large file downloads from mainframe computers. Others may not have compatible software. If an agency truly intends to improve the business functions being measured, it needs to be sure that the data needed to monitor the performance measure are available at the level within the organization that is fundamentally responsible for the function.

For interagency access to data, network connections to databases can provide common and convenient pathways to data. Web technologies have created an opportunity for external sources to have access to data. However, most agencies are just starting to explore the potential for web technology to address data-sharing issues. At first glance, it appears to be an easy solution to many of the legacy problems of accessing data. However, web technology does not address many of the definition or location issues discussed above. Web technology is also in its infancy and is changing rapidly, causing development and compatibility problems. For example, web technologies might be used to enable local governments to have access to state databases that contain local data. Security is an even greater concern in this arena because of the number of potential users. Many questions need to be answered before the data can be shared over the web, such as

- Who has access to which data?
- Is there permission to modify data?
- Can data be downloaded?
- Can the system handle the number of users?

Summary and Conclusions

Reliable data are essential to any system of performance measurement. As measures are developed, policy makers and managers need to consider whether a measure can be routinely reported. Are the data available? Can data be collected at a reasonable cost? Are existing sources of data compatible, and if so, can they be used together in a meaningful manner? Can data be analyzed and presented in a way that will be meaningful to their audience? Are the measures themselves meaningful to the needs, interests, and values of the agency's customers? Answering all of these and other questions must be a part of developing performance measures. If they are not answered correctly, then performance measures will be haphazard and may do the agency more harm than good.

Life-cycle Environmental Inventory of Passenger Transportation in the United States

Abstract

Energy use and emission factors for passenger transportation modes typically ignore the total environmental inventory which includes vehicle non-operational components (e.g., vehicle manufacturing and maintenance), infrastructure components, and fuel production components from design through end-of-life processes. A life-cycle inventory for each mode is necessary to appropriately address and attribute the transportation sector's energy and emissions impacts to reduction goals instead of allowing tailpipe emissions to act as indicators of total system performance.

The contributions of U.S. passenger transportation modes to national energy and emissions inventories account for roughly 20% of U.S. totals, mostly attributed to gasoline consumption. Furthermore, world consumption of primary energy amounted to 490 EJ in 2005 with the U.S. responsible for 110 EJ, or 21% of the total. This means that passenger transportation in the U.S. accounts for roughly 5% of global primary energy consumption annually. With a predominant fossil fuel energy base, the impacts of U.S. passenger transportation have strong implications for global energy consumption, U.S. energy security, and climate change. Furthermore, criteria air pollutant emissions from transportation (passenger and freight) are also significant, accounting for 78% of national CO, 58% of NOX, 36% of VOCs, 9% of PM2.5, 2.6% of PM10, and 4.5% of SO2 emissions. These emissions often occur near population centers and can cause adverse direct human health effects as well as other impacts such as ground-level ozone formation and acid deposition.

To appropriately mitigate environmental impacts from transportation, it is necessary for decision makers to consider the life-cycle energy consumption and emissions associated with each mode. A life-cycle energy, greenhouse gas, and criteria air pollutant emissions inventory is created for the passenger transportation modes of automobiles, urban buses, heavy rail transit, light rail transit, and aircraft in the U.S. Each mode's inventory includes an assessment of vehicles, infrastructure, and fuel components. For each component, analysis is performed for material extraction through use and maintenance in both direct and indirect (supply chain) processes.

For each mode's life-cycle components, energy inputs and emission outputs

are determined. Energy inputs include electricity and petroleum-based fuels. Emission outputs include greenhouse gases (CO2, CH4, and N2O) and criteria pollutants (CO, SO2, NOX, VOCs, and PM). The inputs and outputs are normalized by vehicle lifetime, vehicle mile traveled, and passenger mile traveled. A consistent system boundary is applied to all modal inventories which captures the entire life-cycle, except for end-of-life. For each modal life-cycle component, both direct and indirect processes are included if possible. A hybrid life-cycle assessment approach is used to estimate the components in the inventories. We find that life-cycle energy inputs and emission outputs increase significantly compared to the vehicle operational phase. Life-cycle energy consumption is 39-56% larger than vehicle operation for autos, 38% for buses, 93-160% for rail, and 19-24% for air systems per passenger mile traveled. Life-cycle greenhouse gas emissions are 47-65% larger than vehicle operation for autos, 43% for buses, 39-150% for rail, and 24-31% for air systems per passenger mile traveled. The energy and greenhouse gas increases are primarily due to vehicle manufacturing and maintenance, infrastructure construction, and fuel production. For criteria air pollutants, life-cycle components often dominate total emissions and can be a magnitude larger than operational counterparts. Per passenger mile traveled, total SO2 emissions (between 350 and 460 mg) are 19-27 times larger than operational emissions as a result of electricity generation in vehicle manufacturing, infrastructure construction, and fuel production. NOX emissions increase 50-73% for automobiles, 24% for buses, 13-1300% for rail, and 19-24% for aircraft. Non-tailpipe VOCs are 27-40% of total automobile, 71-95% of rail, and 51-81% of air total emissions. Infrastructure and parking construction are major components of total PM10 emissions resulting in total emissions over three times larger than operational emissions for autos and even larger for many rail systems and aircraft (the major contributor being emissions from hot-mix asphalt plants and concrete production). Infrastructure construction and operation as well as vehicle manufacturing increase total CO emissions by 5-17 times from tailpipe performance for rail and 3-9 times for air.

A case study comparing the environmental performance of metropolitan regions is presented as an application of the inventory results. The San Francisco Bay Area, Chicago, and New York City are evaluated capturing passenger transportation life-cycle energy inputs and greenhouse gas and criteria air pollutant emissions. The regions are compared between off-peak and peak travel as well as personal and public transit. Additionally, healthcare externalities are computed from vehicle emissions. It is estimated that life-cycle energy varies from 6.3 MJ/PMT in the Bay Area to 5.7 MJ/PMT in Chicago and 5.3 MJ/PMT in New York for an average trip. Life-cycle GHG emissions range from 480 g C02e/PMT in the Bay Area to 440 g C02e/PMT for Chicago and 410 g C02e/PMT in New York. CAP emissions vary depending on the pollutant with differences as large as 25% between regions. Life-cycle CAP emissions are between 11% and 380% larger than their operational counterparts. Peak travel, with typical higher riderships, does not necessarily environmentally outperform off-peak travel due to the large share of auto PMT and less than ideal operating

conditions during congestion. The social costs of travel range from 51 cent (in 2007 cents) per auto passenger per trip during peak in New York to 6 cents per public transit passenger per trip during peak hours in the Bay Area and New York. Average personal transit costs are around 30 cents while public transit ranges from 28 cents to 41 cents.

This dissertation was completed with Professor Arpad Horvath serving as the advisor. This document supercedes the University of California, Berkeley, Center for Future Urban Transport papers, vwp-2007-7 and vwp-2008-2. Additional project information can be found at http://www.sustainable-transportation.com.

POLICY FACT SHEET: Positioning transit to reduce life-cycle environmental impacts for sustainability goals

Mikhail Chester, PhD, Stephanie Pincetl, PhD, Zoe Elizabeth, William Eisenstein, PhD, and Juan Matute

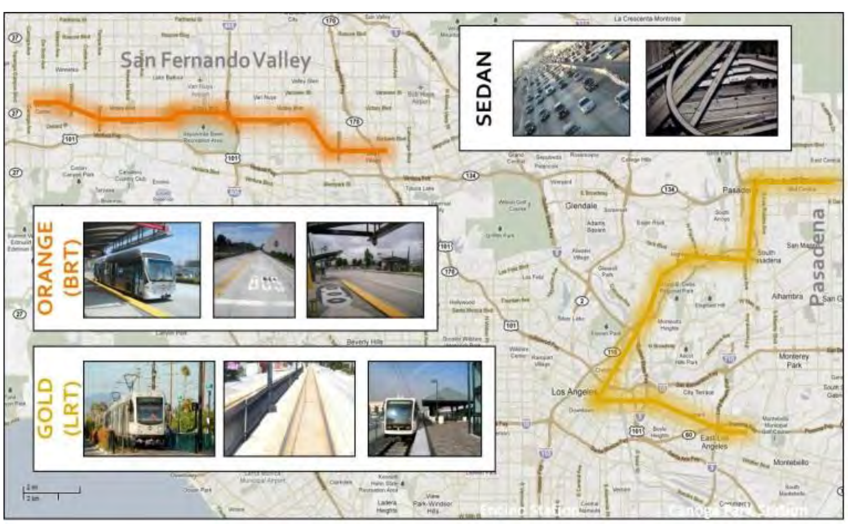
Introduction

Public transit systems are often seen as energy and environmental improvements to automobile travel. Few studies, however, have comprehensively assessed the full effects of the decision to construct and operate public transportation systems. The **California Center for Sustainable Communities (CCSC) at UCLA** recently released a study that compares the life-cycle impacts of two public transportation options with a private automobile in Los Angeles.

The Study

The study compared **Los Angeles County Metropolitan Transportation Agency's (Metro)** Orange line Bus Rapid Transit (BRT) and Gold line Light Rail Train (LRT) to a sedan automobile (Toyota Camry). The LCA included vehicle, infrastructure, and energy production components in addition to traditional vehicle propulsion effects. Using LA Metro system-specific data, researchers compared the three modes at present technology standards and also compared the modes with expected future improved standards.

Figure 1 - System Map



Project Overview

This project compares the life-cycle impacts of the Gold Line light rail (LRT), the Orange Line bus rapid transit (BRT) and a passenger sedan automobile in Los Angeles

Key Findings

- The public transit options require less energy and produce fewer greenhouse gas emissions per passenger mile traveled than the personal automobile
- Maximizing the mode shift from single occupant vehicles (SOV) to public transit is essential to maximizing the environmental benefits
- Life-cycle assessment (LCA) reveals an additional 48-100% greenhouse gas emissions for each vehicle type and as much as 6200% additional air pollution emissions compared to tail-pipe only accounting
- The benefits from reduced automobile travel outweigh the environmental costs of a new transit system.
- It is possible that a policy that focuses on reducing one pollutant may increase another
- Special consideration should be given to tradeoffs between global GHG emissions and regional air pollution impacts

Table 1 - LCA Modes Analyzed

Mode	Current Technology	Future Technology
Passenger Automobile	35 mpg	55 mpg
Bus Rapid Transit	Current Average Emission Profile	Future Engine Emissions Certification
Light Rail Train	Current LADWP Electricity Mix	Renewable Portfolio Standard (RPS) Electricity Mix

Findings

- The LCA reveals that all three modes will be cleaner in the future. Significant environmental benefits will be achieved in the long-term as a result of vehicle technology changes and energy and environmental policy initiatives.
- The Orange Line and the Gold Line reduce energy consumption and GHGs and lower smog formation by reducing private automobile use.

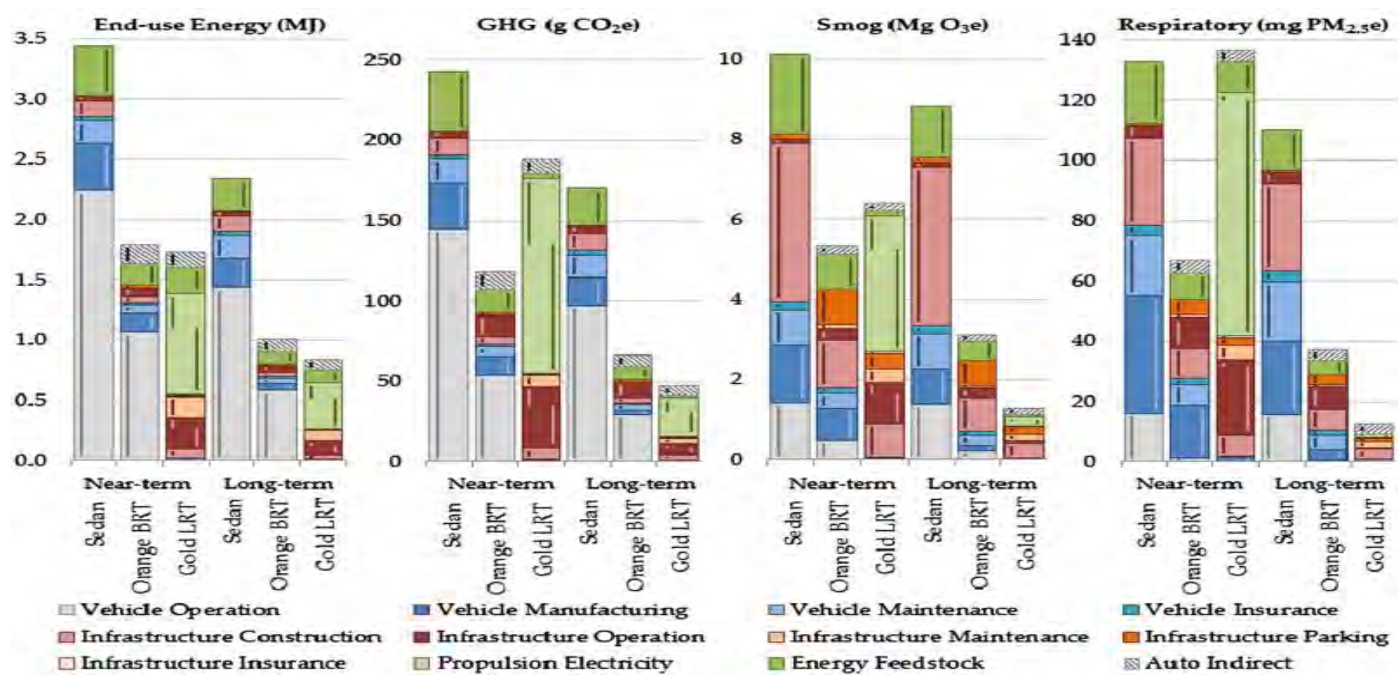
Project Specifics

Contractor: UCLA's Institute of the Environment & Sustainability
County: Los Angeles County
Contract: PIER 500-10-009

This report is published in **Environmental Research Letters**, doi:10.1088/1748-9326/8/1/015041. To access the full report, visit the **CCSC website** or view **Infrastructure and automobile shifts: positioning transit to reduce life-cycle environmental impacts for urban sustainability goals** (http://iopscience.iop.org/1748-9326/8/1/015041/) in Environmental Research Letters, an open access journal.

Figure 2 - Life-cycle per passenger mile traveled results for average occupancy vehicles.

For each impact both near-term and long-term results are shown for each mode.



Findings (continued)

Energy Consumption and GHG Emissions

- In the long term, fuel economy gains, improved vehicle technology, and a cleaner electricity mix will have the greatest impacts on reducing energy consumption and GHG emissions in Los Angeles

Air Emissions

- Light rail transit relies on electricity propulsion, which has the potential to increase out-of-basin respiratory impacts. The city is currently pursuing an aggressive effort to divest in coal-powered electricity and increase their renewable portfolio standard for cleaner electricity, which will lead to significant long-term benefits.

Policy Implications

- The energy and environmental benefits of the Metro Los Angeles Gold Line light rail and Orange Line bus rapid transit outweigh the environmental costs of constructing and operating the system.
- According to the study's projections, the Orange Line will pay back on greenhouse gas emissions in its 2nd decade of operation and the Gold Line to pay back on greenhouse gas emission in its 4th decade.
- Cities rely on complex and dynamic energy and material supply chain networks. LCA reveals where in the manufacturing process (vehicle, infrastructure, and energy production) emissions occur. Policy makers can reduce overall life-cycle impacts by contracting with suppliers that use best practices to reduce environmental impacts through all phases of construction and use.
- Local vehicle trips trigger energy use and emissions that extend beyond Los Angeles. Life-cycle assessment reveals that policymakers should focus on ways to reduce the absolute number of cars in use (and hence avoid their manufacture) since vehicle operation is only one component of emissions and pollution.
- Planners and policy makers should position new transit in locations that ensure that passengers will transition from driving. This will accelerate the environmental payback period for upfront construction costs.

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FAQ: What is life-cycle assessment?

New Study Released: Positioning Transit to Reduce Life-cycle Environmental Impacts for Urban Sustainability Goals

Dr. Mikhail Chester of Arizona State University, together with the **California Center for Sustainable Communities (CCSC) at UCLA**, recently published a life-cycle assessment of transportation options in Los Angeles. The study analyzed bus rapid transit, light rail transit, and passenger vehicle travel to assess the near-term and long-term changes in energy consumption greenhouse gas emissions, criteria pollutant emissions, and the potential for smog formation and respiratory impacts.

What is life-cycle assessment (LCA)?

Life-cycle assessment is a framework for assessing the cradle-to-grave environmental and economic impacts of complex systems. LCA establishes methods for evaluating each stage, from extraction of raw materials, processing of those materials, manufacturing, use, maintenance, and disposal, as well as transport between. The purpose of LCA is to holistically view the entire range of environmental effects of a policy (or product) and to inform the decision-making process.

Figure 1- Life-cycle assessment considers a wide array of processes associated with new transit projects

What are the benefits of LCA?

- To identify the transfer of environmental impacts from one area to another (e.g., eliminating air emissions by creating a water runoff problems) and/or from one life-cycle stage to another (e.g., from use and reuse of the product to the raw material acquisition phase) (EPA, 2006)
- To illuminate tradeoffs that decision-makers must be aware of when implementing environmental policy. For example, legislation targeted at reducing one type of emission could result in increased emissions by another pollutant.
- To quantify and identify the spatial and temporal emissions of various policies.

Source: US Environmental Protection Agency (EPA). (2006) *Lifecycle assessment: Principles and practice* (US EPA Report - EPA/600/R-06/060). Retrieved from http://www.epa.gov/nrmrl/std/lca/lca.html

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about

Mr. Peterman has over 15 years of experience in the design of Intelligent Transportation Systems, traffic signals and signal systems. He has been heavily involved in the design and implementation of ITS systems for dozens of agencies, including Caltrans, public and private entities, and institutions. He has also been responsible for the development and implementation of specialized communications systems for transportation projects, including a wide array of hardware and software. Josh currently serves as Chair of the ITS California Board of Directors of ITS California.

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- Bike/Ped Facilities Planning and Design
- Traffic Safety Program
- Traffic Impact Analysis

publications & presentations

- *Automated and Connected Vehicles: Their Impact on Transportation Planning and Infrastructure*, Fehr & Peers, 2014.
- *Using ITS to Plan for Emergency Response in Santa Clara County,* presented at ITS America Annual Meeting in Orlando FL, 2012
- *Traffic Signal Design*, an ASCE Webinar, delivered annually since 2010
- *TE-02 Traffic Signal Design*, UC Berkeley Tech Transfer, Lead Instructor, 2015
- *Evaluation of Incident Detection Methodologies*, presented for M.S. Thesis, University of Texas, 1999
- *Video Over Copper Networks; The Tale of Three Cities*, presented at ITE Technical Conference, Las Vegas NV, 2005
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