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## MEMORANDUM

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Date: May 20, 2013

Project #:  
123830

To: Chris Ratekin  
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From: Alice Chen/David Reinke

Project: Implementation of Smart Mobility Framework

Subject: Deliverable 3.2: Literature and "Practice in Progress" Review - DRAFT

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## INTRODUCTION

In order to identify the leading edge of sustainable and multi-modal transportation planning practice and how it may be applied in California, subject matter experts and literature review sources were identified. This review covers corridor management, performance measurement, regional and sub-regional long range transportation planning, project development, and project analysis. However, since this effort is part of the implementation of the SMF, the literature review and interviews emphasize corridor management and sub-regional long-range transportation planning, which are the two areas covered in our study - Pilot Area 1 (PA1) for the District 4 I-680 Corridor System Management Plan (CSMP) and Pilot Area 2 (PA2) for the South Bay Cities Council of Governments (SBCCOG) Sub-regional Long Range Transportation Plan. This memo summarizes the research, interviews, and findings from this effort. Detailed notes from the interviews are provided in the appendix.

## BACKGROUND

These efforts focused on the developments in research, guidance, performance measures, and tools released or under development since the release of the Smart Mobility Framework (SMF) in 2010, while building off the Caltrans Smart Mobility Preliminary Investigations that commenced in 2012 so as not to duplicate efforts and focus on applications for the two pilot area studies.

## Caltrans Preliminary Investigations

Our approach was to build off the survey of current practice and related research on Smart Mobility that was conducted for Caltrans as a Preliminary Investigation (PI) (dated April 25, 2012).<sup>1</sup> This first PI examined national and international research as well as federal, state, and regional activities to assess the current state of the practice in multimodal, sustainable transportation planning. The April 2012 PI focused on guidance, research, and tools that had been developed or initiated since the January 2010 publication of *Smart Mobility 2010*. The PI covered three topic areas:

- National Guidance and Tools
- Transportation Agency Tools
- Related Research

To avoid duplication, the April 2012 PI was reviewed and used as a starting point for this effort. Of the tools and measures presented in this first investigation, the following tools were considered for follow-up for potential application to the pilot area studies:

- FHWA launched INVEST (Infrastructure Voluntary Evaluation Sustainability Tool) on October 10, 2012, as a web-based tool to help transportation agencies integrate sustainability into their programs and projects. INVEST considers the full lifecycle of roadway projects from planning to project development to operations and maintenance with separate criteria for evaluation.
- Least Cost Planning is a model developed by the Oregon Department of Transportation that includes livability, safety, equity, economic vitality, and environmental stewardship as well as traditional measures, such as capital costs.
- MOSAIC (Model of Sustainability and Integrated Corridors) was developed for the State of Maryland to estimate the sustainability impact of multimodal highway corridor improvement options during the screening process. Six indicators (mobility, safety, socio-economic impact, natural resources, energy and emissions, and cost) and more than thirty performance measures were defined as evaluation criteria. The MOSAIC tool provides a high level assessment of highway build options in an Excel spreadsheet environment tool, which may not be applicable for these two pilot area studies. However, future improvements to the tool will consider multimodal improvements in highway projects and integrating the tool into the SHA Enterprise GIS environment for statewide applications in Maryland.

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<sup>1</sup> Link to first PI:

[http://www.dot.ca.gov/newtech/researchreports/preliminary\\_investigations/docs/smart\\_mobility\\_preliminary\\_investigation\\_4-25-12.pdf](http://www.dot.ca.gov/newtech/researchreports/preliminary_investigations/docs/smart_mobility_preliminary_investigation_4-25-12.pdf)

- STARS (Sustainable Transportation Access Rating System) is being developed by the North American Sustainable Transportation Council, a collaboration of public and private sector transportation professionals from Oregon, Washington, California and Nevada. STARS is a planning and evaluation tool that evaluates multimodal access benefits and costs over the full life cycle. STARS is being applied by the Santa Cruz County Regional Transportation Commission (SCCRTC) for their Regional Transportation Plan as well as the Highway 1 corridor study.

As a follow up to the April 2012 PI, Kendra Levine at UC Berkeley posed a series of questions to practitioners using and developing sustainability tools to gauge progress in the field. The questions ranged from broad context related to the objectives of sustainability programs to specific questions on the development and implementation of the tools. The practitioners identified for interview included MPOs/regional agencies, mostly in California, but also the Puget Sound Regional Council, as well as cities, such as Portland and San Francisco, and state DOTs and research centers who have developed or implemented sustainability tools. A copy of this scope with the full list of questions and interviewees is included in the appendices. The November 2012 report presented responses of six transportation agencies. Concurrent with this second PI, our review of best practices was conducted through interviews with subject matter experts focused on potential applications for the two pilot areas.

This limited response prompted a third investigation which focused on tools and practices of selected State DOTs and California MPOs. The agencies who participated in this third PI included four states agencies (Illinois DOT, North Carolina DOT, Rhode Island Statewide Planning Program, and Texas DOT) and four MPOs (Metropolitan Transportation Commission (MTC), Sacramento Area Council of Governments (SACOG), San Francisco County Transportation Authority (SFCTA), and Santa Cruz County Regional Transportation Commission (SCCRTC)). This third PI was completed in March 2013.<sup>2</sup>

Although the performance measures for the I-680 CSMP study had already been determined by the time this third PI was completed and the tools (activity-based travel demand model and UrbanSim) developed by the MTC for their RTP/SCS were still in development in Fall 2012, these tools may be applied for future CSMP work in the San Francisco Bay Area. Similarly, the UrbanSim tool may be considered for application by other MPOs and regional agencies in their transportation planning efforts, including the South Bay Cities COG.

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<sup>2</sup> The link to the full March 2013 PI is:

[http://www.dot.ca.gov/newtech/researchreports/preliminary\\_investigations/docs/caltrans\\_smart\\_mobility\\_preliminary\\_investigation\\_3-21-13.pdf](http://www.dot.ca.gov/newtech/researchreports/preliminary_investigations/docs/caltrans_smart_mobility_preliminary_investigation_3-21-13.pdf)

## INTERVIEWS

As originally intended, the findings from this review would inform the refinement of the detailed work plans for each of the pilot areas. However, due to the timing of the I-680 CSMP, which moved forward quicker than this contract, the PA1 effort focused on the performance measures and the metrics, tools, and data needed to apply these broader sustainability measures in the SMF. For PA2, subject matter experts and research specific to the South Bay Cities were included based on feedback solicited from Metro during the initiation of that effort in July 2012. Subject matter experts were identified and a set of questions were developed for the interviews. Table 1 shows the persons interviewed and their areas of expertise.

Name	Organization	Contact	Expertise
Jeffrey Ang-Olson	ICF International	916.213.7674 <a href="mailto:jangolson@icfi.com">jangolson@icfi.com</a>	SMF co-author. EPA Guide to Sustainable Transportation Performance Measures
Dr. Marlon Boarnet	University of Southern California	949.824.7695 <a href="mailto:boarnet@usc.edu">boarnet@usc.edu</a>	Accessibility, Travel Behavior, and New Urbanism: Case Study of Mixed-Use Centers and Auto-Oriented Corridors in the South Bay Region of Los Angeles, California
Ginger Dykaar	Santa Cruz County Regional Transportation Commission	831.460.3200 <a href="mailto:gdykaar@sccrtc.org">gdykaar@sccrtc.org</a>	Application of STARS to regional transportation plan update.
Peter Hurley and Kelly Rodgers	North American Sustainable Transportation Council	206.228.1438 <a href="mailto:Peter@transportationcouncil.org">Peter@transportationcouncil.org</a>	STARS (Sustainable Transportation Access Rating System)
Jonathan Levine	University of Michigan, Ann Arbor	<a href="mailto:jnthnlvn@umich.edu">jnthnlvn@umich.edu</a>	Accessibility based performance measures.
Douglas MacDonald	Independent consultant	206 420 3453 <a href="mailto:dbmacdonal@earthlink.net">dbmacdonal@earthlink.net</a>	Secretary of Transportation, State of Washington (2001 – 2007); originated Washington State Gray Notebook on performance measures
Susan Zielinski	University of Michigan, Ann Arbor	734.763.1190 <a href="mailto:susanz@umich.edu">susanz@umich.edu</a>	SMART (Sustainable Mobility & Accessibility & Transportation)

**Table 1. Persons interviewed**

### Interview Questions

Persons interviewed were asked about their views on performance measures in relation to the two pilot study areas. When possible, relevant publications by the individuals were reviewed prior to the interview. Questions for each individual were tailored to their specific area of expertise and fall into the following areas:

- What specific performance measures do you recommend?
- What goals and objectives are these performance measures intended to inform?
- What are the data sources for these performance measures? How difficult and expensive are the data to collect?
- What analysis tools exist for estimating these performance measures? Are you aware of any new analysis tools under development?
- How do these performance measures reinforce or conflict with performance measures currently in common use such as level of service?
- Can these performance measures be combined with other performance measures in a commensurate way, such as in a benefit-cost analysis?
- Where have these performance measures been used?
- Can you describe what difficulties were encountered in using these performance measures, and how these difficulties were overcome?

## SUMMARY OF FINDINGS

This summary of finding is based primarily on the interviews of which detailed interview notes are presented in the appendix, but also include information from review of relevant publications by the interviewee.

When it comes to the sustainability tools and practice, the general findings from our interviews are similar to the state of the practice from the PIs.

- Institutional Policies: Many state DOTs are developing and implementing institutional policy changes to incorporate sustainable transportation into agency practice. A next step is to follow up with other state DOTs, such as PennDOT and NJDOT, in sharing lessons learned from implementation of the Smart Transportation principles or Washington State DOT on the performance measures in the Gray Notebook.
- Stakeholder and Public Engagement: Performance measures are a way of communicating planning results to the public and making the process more transparent. Performance measures should be reflective of the community values and objectives to establish priorities. The challenge comes in building consensus on objectives.
- Project Delivery: The decision tool developed by the Transportation for Communities – Advancing Projects through Partnership (TCAPP) provides a framework for stakeholder engagement throughout the planning process to expedite project delivery.

### Performance Measures

- Performance measure development will always be a work in progress as community values change. We need to be making incremental progress on better performance measures.
- Mobility and accessibility are not the same thing. In the past we have tended to concentrate on mobility. But it is accessibility that is really important.
  - In developing the Santa Cruz County RTC's RTP, level of service (LOS) is not in any goals, rather access is the goal. Travel time reliability and speed consistency have replaced LOS. Average trip distance is used as a measure to encourage shorter trip on arterials rather than longer trips on freeway.
- Performance measures should be applied during pre- and post-project evaluations to measure success at meeting the performance targets.
- Development of new performance measures is still ongoing. Most of the experts interviewed – as well as most of the literature sources on performance measures – agree that “something new” is needed beyond auto level of service. Most proposed new performance measures have a lot of similarities to each other, but there has been no “standardization” on a set of performance measures that reflect quality of life objectives.

- Traditional auto level of service measures, long dominant in evaluation of alternatives, need to be supplemented with other measures that reflect values such as livability, economic robustness, and health and safety. Indeed, auto level of service may be much less important in the overall scheme of things.
- Use of HCM for multimodal level of service as a sample along a corridor due to data and resource availability to cover the entire corridor. (This approach was taken for PA1 as part of the Complete Street Assessment.)
- When including equity as a performance measure, consider equity issues at the destination end and not just the home end.
- For emissions, consider fossil fuel consumption as a measure rather than VMT.
- Weight different SMF measures into a composite measure, such as benefit/cost. (The Caltrans b-c tool was included as one of the performance measures for the I680 CSMP.)

## Tools and Data

- Tools are in constant development particularly with the need in California to prepare the Sustainable Communities Strategies (SCS)/RTP. We still lack a generally agreed-on set of tools to measure and analyze non-traditional performance measures.
- We may need to reconsider how we go about data collection and monitoring in order to provide more information for these performance measures. Recognition that the tools need to be developed and data needs to be available to support tools.
- Need for pedestrian and bike counts, not just mode share. National Bicycle and Pedestrian Documentation Project (NDP) is potential source of counts that can be used to develop bike forecasting models. NHTS with the CA supplement is another source, but has only a small sample size for the pilot areas, particularly at the neighborhood level, which is being considered for PA1.
- For bicycling, additional analysis tools include the low-stress network analysis, which is being used in San Jose.
- SafeTREC's study on the effects of roadside design features provides data to quantify the effects of roadside design features to improve the environment for pedestrians and bicyclists to increase safety and use by these modes.<sup>3</sup>

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<sup>3</sup> University of California Berkeley Safe Transportation Research and Education Center. "The Effects of Transportation Corridors' Roadside Design Features on User Behavior and Safety, and their Contributions to Health, Environmental Quality, and Community Economic Vitality," prepared for Caltrans, Division of Research and Innovation, April 1, 2011.

- To evaluate non-traditional/non-highway projects and programs, consider specific metrics from the EPA Guide to Sustainable Transportation Performance Measures that could be applied on a subregional scale for the PA2 study.
- As PA2 moves to arterial corridor-based study areas, we can look to the City of San Diego's Rosecrans Corridor Mobility Study.

## LITERATURE AND OTHER AGENCY PRACTICE REVIEW

Our review of the literature and other agency practices is based on sources identified by Caltrans and our knowledge of sources on performance measures from previous work. These are in addition to the sources reviewed in the PIs or were reviewed in preparation for the interviews. The following is a list of sources:

- South Bay Cities Council of Governments: The work done by SBCCOG was reviewed to provide the context for PA2 as well as in preparation of the interview with Marlon Boarnet.
- EPA Guide to Sustainable Transportation Performance Measures: This guide was published in August 2011 after the SMF and presents possible metrics for each performance measure.
- California Air Resources Board research in support of SB 375: policy briefs and background papers: These policy briefs provide a potential source for quantifying benefits, specifically VMT reduction, of non-traditional projects or projects that are not addressed with current models and tools.
- Least-cost planning/integrated transportation planning: This approach is used by the State of Washington for comprehensive evaluation of transportation system alternatives.
- Pennsylvania and New Jersey Departments of Transportation: These agencies have developed Smart Transportation principles that have been incorporated into guidance and may share some lessons learned from their own implementation efforts.
- North Carolina Sustainable Communities Task Force: This initiative partners the North Carolina DOT with the Department of Environment and Natural Resources, which may suggest opportunities for Caltrans to partner with other state agencies to further the SMF principles.

## SOUTH BAY CITIES COUNCIL OF GOVERNMENTS

The South Bay Cities Council of Governments conducted research on different types of mixed-use districts for dealing with additional growth and density in the South Bay area [32]. The purpose of the research was to identify strategies that are tailored to the South Bay and its cities, rather than adopting a cookie-cutter formula derived from principles of "smart growth" or "New Urbanism". The research concentrated on finding strategies that would allow additional housing to be accommodated while minimizing the traffic effects.

The following is a summary of the conclusions of the study (quoted directly from the report's executive summary):

1. Almost Everybody Drives to Work

Typical of metropolitan Los Angeles, about three-quarters of the residents of our study areas drive to work alone, and they travel close to a half-hour to reach their jobs. Most of the remaining one-quarter of the residents either carpool or work at home. Few employees commute by public transit, bicycling, or walking. There appears to be more public transit use among lower-income residents.

2. Transportation performance is improved through a concentration of many activities, not just additional housing density

The mere introduction of more housing density does not necessarily alter people's travel habits. Our research contains considerable evidence that a concentration of activities, rather than just higher housing densities, can have an impact on transportation performance. The more that housing, employment, and certain types of retail and service activities are located in close proximity to one another, the more likely nearby residents are to patronize their local area and the more likely they are to walk, rather than drive, for their daily errands.

3. Transportation performance is improved through a specific mix of retail businesses

It is clear that the presence of retail businesses in a mixed-use district can make a mixed-use district more attractive to surrounding residents and affect both their travel patterns and the mode of transportation they use. However, it is not the mere presence of retail businesses that makes the biggest difference. Rather, the presence of certain types and combinations of retail businesses affects performance.

4. Centers and Corridors Are Different

Because the business district in a center is several blocks deep, businesses are organized in a more concentrated way. Among other things, this appears to reduce the overall "trip length" for nearby residents, because they do not have to travel up and down a corridor to reach an individual business. Corridors, by contrast, are designed to provide businesses and services primarily for those traveling up and down the arterial street.

5. Some People Will Always Drive

Remarkably, even in those mixed-use districts with high-density housing, a good mix of retail businesses, and a pedestrian-friendly environment, 25% to 40% of nearby residents still drive from their homes to the businesses in the district. In the case of corridors, most people drive to the nearby business district even when it is extremely close. The bottom

line is that in both cases, a large percentage of nearby residents drive ¼ of a mile or less to their destination.

The report contained the following recommendations for creating and enhancing mixed-use districts in the South Bay:

1. **Focus on concentration, not density.** This means that rather than simply increasing housing density, cities should emphasize creating a dense concentration of activities of all kinds in the mixed-use district including employment, shopping, and recreational and civic uses in addition to housing.
2. **Focus on “horizontal mixed use” as well as “vertical mixed use”.** “Mixed-use” does not simply mean that uses should be placed on top of each other; they can also be placed in close proximity to one another. This is especially applicable where building height is a sensitive issue.
3. **Focus on the mix of business and services.** The research repeatedly found that both trip capture and mode split are heavily influenced by the businesses and services available in the mixed-use district. Although there is no fixed formula for what the mix should be, the rules of thumb suggest the following strategies:
  - a. Focus on food
  - b. Focus on neighborhood services
  - c. Understand and strengthen the role the mixed-use district plays in the subregional economy
  - d. Combine planning and economic development efforts
4. **Find and strengthen the “center” aspect of a mixed-use district wherever possible.** Most of the South Bay is located along commercial corridors; these cannot be converted into centers. But it is possible to find locations throughout the South Bay that have center-like characteristics or lend themselves to a center-oriented approach such as:
  - a. Locations a center could be created in large blocks of land adjacent to the corridor
  - b. Locations that have a corridor design but do not have much through traffic
5. **Experiment with neighborhood vehicles and neighborhood parking strategies.** Mixed-use districts – even successful ones – will still draw a large number of drivers. The use of smaller neighborhood vehicles and alternative parking strategies could make better use of the parking resources already available in the mixed-use districts. Most centers and corridors had ample parking and low parking use rates. Creating a concentration of activities would allow more drivers to park only once within the mixed-use district. Strategies to achieve this include:
  - a. Encourage public use of private parking lots and garages

- b. Unbundle parking requirements for new condominiums
  - c. Create a credit system for unused on-street parking
6. **Consider a multijurisdictional effort to revamp corridors into boulevard-type streets more appropriate to mixed-use districts.** Some arterials could be revamped to serve a less traditional arterial role and instead emerge as locations that are more oriented toward local residents. Such corridors would probably require inter-jurisdictional cooperation.

## EPA GUIDE TO SUSTAINABLE TRANSPORTATION PERFORMANCE MEASURES

This EPA guide [47] describes opportunities to incorporate environmental, economic, and social sustainability into transportation decision-making through the use of performance measures. The guide provides examples of best practices in sustainable transportation performance measurement that are being applied across the country.

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

The guidebook reviews application of sustainable performance measures can be to a number of major decision-making phases including the following:

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

The guidebook describes 12 performance measures that can readily be applied in transportation decision-making. It is primarily concerned with transportation decision-making at the regional or metropolitan level. For each measure, the guidebook presents possible metrics, summarizes the

relevant analytical methods and data sources, and illustrates the use of each measure by one or more transportation agencies. The 12 profiled measures:

- Transit accessibility
- Bicycle and pedestrian mode share
- Vehicle miles traveled per capita
- Carbon intensity
- Mixed land uses
- Transportation affordability
- Distribution of benefits by income group
- Land consumption
- Bicycle and pedestrian activity and safety
- Bicycle and pedestrian level of service
- Average vehicle occupancy
- Transit productivity

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

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

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

For the SMF, some of the specific metrics from this guidebook may be applicable on a subregional scale for PA2 where the current models available do not cover the non-auto modes.

## CALIFORNIA AIR RESOURCES BOARD RESEARCH IN SUPPORT OF SB 375

The State of California enacted Assembly Bill 32, the Global Warming Solutions Act, which requires the state to develop regulations that will reduce greenhouse gas emissions to 1990 levels by 2020. The State has also enacted Senate Bill 375, the Sustainable Communities and Climate Protection Act, which requires the California Air Resources Board (CARB) to develop regional greenhouse gas emission targets and requires Metropolitan Planning Organizations (MPOs) to prepare a sustainable communities strategy that demonstrates how the region will meet its greenhouse gas emission targets.

As part of this effort, CARB commissioned a set of research papers to summarize the literature on different policies to reduce greenhouse gas emissions [6]. Each topic is covered by a policy brief and a background technical document. The papers include the following policy assessments that may apply to the SMF pilot studies:

- Parking pricing
- Road user pricing
- Employer based trip reduction
- Pedestrian strategies
- Bicycle strategies
- Transit service
- Telecommuting
- Voluntary travel behavior change programs

Each policy brief contains the following sections:

- Policy description
- Size of the effect of the policy on reducing VMT
- Summary of studies
- Assessment of the quality of the evidence
- Caveats
- Effects on greenhouse gas emissions
- Co-benefits with other strategies
- Examples
- References

## Transportation strategies

### ***Parking pricing***

The policy brief on parking pricing identifies the following types of parking pricing strategies [36, 37]:

- Long/short-term fee differentials
- On-street fees and resident parking permits
- Workplace parking pricing

The evidence on parking pricing is scarce. Much of the literature is over 15 years old. On average, studies indicate that a 10% increase in parking price produces about a 3% reduction in the demand for parking spaces. The net effects on VMT have not been directly quantified, although there is some evidence on the effectiveness of California's parking cash-out law on vehicle trip reduction (see Section 5.10).

### ***Road user pricing***

Road user pricing policies that were investigated included facility pricing, cordon pricing, and distance charging [38, 39]. The review found the following:

- For toll facilities a 1% increase in tolls produced traffic reductions averaging about 0.1% - 0.2%.
- Results from cordon pricing projects varied because of the different nature of the projects. The London cordon pricing scheme resulted in a 16% reduction in traffic volumes. Other cordon pricing schemes showed volume reductions between 12% - 23%. In Singapore a 1% price increase produced trip reductions between 0.21% - 0.31%.
- There are no known examples of distance-based charging implementations.

All assessments of road user pricing were based on numbers of trips reduced rather than VMT reductions.

### ***Employer-based trip reduction***

Employer based trip reduction programs covered in the research [3, 23] included the following:

- Employer-provided alternative mode services such as carpool facilitation, vanpool service, car sharing, and a guaranteed ride home program
- Financial incentives for users of alternate commute modes
- Worksite facilities for cyclists such as showers, lockers, and racks
- Alternative work schedules
- Information and marketing

Studies reviewed included the following:

- Los Angeles metropolitan area trip reduction program – Average vehicle ridership increased 2.7%; carpooling increased to 33.3% from its initial 13.8% share;
- Washington State passed a commute trip reduction law in 1991. The average VMT from commute trips at participating work sites decreased by 6%; and,
- A study of commute trip reduction efforts in Denver, Houston, San Francisco, and Washington DC showed a 4.16 to 4.79% trip reduction.

Overall the reviewers concluded that a 4% to 6% vehicle trip reduction was a feasible target for employer-based trip reduction programs, although higher reductions were noted for specific programs.

### ***Pedestrian strategies***

The review of pedestrian strategies [31, 12] cited studies of improvements to pedestrian infrastructure. Each of the studies reviewed used one of the following measures of the walking environment:

- Street characteristics: measures of sidewalk width, sidewalk coverage, or sidewalk length
- Pedestrian environment quality: composite measure of several characteristics of the walking environment, such as sidewalks, street crossings, and topography
- Neighborhood type: a simple classification reflecting many characteristics of the neighborhood, including the pedestrian environment

The studies reviewed found the following:

- Effects of sidewalk characteristics on walking are small. The amount of walking was found to increase from 0.09% – 0.27% for an increase in 1% in sidewalk coverage, length, or width.
- Effects of pedestrian environment quality are similar to those for sidewalk characteristics; a 1% increase in pedestrian environment quality was associated with a 0.12% – 0.18% increase in walking.
- Neighborhood type can have a significant effect on walking. The studies cited showed that traditional neighborhoods have 44% to 120% greater walking rates than conventional suburban neighborhoods. A New Urbanist neighborhood in Chapel Hill, NC showed a threefold increase in walking over conventional suburban neighborhoods.

It was found that increases in walking did not necessarily translate to decreased driving. One study found no change in vehicle travel associated with increased presence of sidewalks, while three other studies showed a 0.02% to 0.19% decrease in VMT for a 1% increase in the pedestrian measure (sidewalk length, presence of sidewalks, or pedestrian environment factor).

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## ***Bicycle strategies***

The review of bicycle strategies [15, 19] noted the following categories of strategies from Pucher et al. [29]:

- Infrastructure, travel related – Strategies that deal directly with bicycle travel such as bike lanes, bike paths, signed routes, and traffic signal phases for bicycles
- Infrastructure, trip end – Provision of bicycle facilities at the trip end such as bike parking, lockers, and showers at workplaces
- Bicycle-specific programs such as bike to work days, bike education, and bike sharing
- General travel programs such as trip reduction programs and Safe Routes to School
- Legal policies such as helmet laws and speed limits

The review found no studies that provide direct evidence of the effect of bicycle strategies on VMT. Further, few studies even provide direct evidence on the effect of bicycle strategies on bicycling. Studies cited showed that increases in bicycle infrastructure by various measures in general showed an increase in bicycling; two of the studies showed decreases in auto use with increases in bicycle infrastructure. Promotional programs were also associated with increases in bicycling for the studies cited. Comprehensive programs that included infrastructure improvements and promotional activities showed large increases in bicycling in two U.S. cities and three other cities. The review cited in particular the results from Portland, Oregon, where a number of bicycle strategies were adopted including various types of infrastructure improvements and promotional activities; the share of workers that commuted by bicycle increased from 1.1% in 1990 to 1.8% in 2000 to 6.0% in 2008.

## ***Transit service***

Studies reviewed in the transit service policy brief [13, 14] included the following:

- Service and frequency increases on the existing system
- System expansion
- Fare reductions

The review found a wide range of changes in transit patronage in response to changes in various service strategies. The studies reviewed showed a service frequency elasticity of about 0.5, while the fare elasticities of the studies reviewed averaged about -0.4. The review stresses that no single elasticity value would apply in all situations.

The review also found that increases in transit patronage do not directly translate into decreases in driving, since not all new transit trips replace driving trips. And because of the generally small mode share in transit in most areas, even large increases in transit patronage usually translate into small decreases in driving.

Effects of different transit strategies are highly contingent on the physical, operating, and economic environments. In general, transit patronage is likely to increase most in response to a frequency increase where existing service is infrequent, for riders who are not dependent on transit, and for discretionary trips.

The review cited projects involving bus rapid transit in Los Angeles and Orange County, California. Both systems showed large increases in bus patronage, although only about one-third of the new riders on Los Angeles Metro system were new riders.

### ***Telecommuting***

Telecommuting can refer either to employees working from home or traveling to a nearby “telecommuting center” that provides communication facilities [18, 22]. The review observed that early forecasts of the effects of telecommuting on travel were overly optimistic. Fewer persons are telecommuting and they are doing it less frequently than early studies predicted.

Nonetheless, for those employees who telecommute the reduction in VMT are significant. The review of existing studies found that personal VMT reduction per telecommuter on telecommuting days ranged between 53.4% – 76.5%; the theoretical 100% decrease in VMT does not occur owing to some additional travel of other kinds on telecommuting days. Studies show that telecommuters average from 1.2 to 2.5 days of telecommuting per week. In California the estimated proportion of the work force that telecommutes is about 1.5% on any particular weekday in 1998; advances in technology and availability of broadband communications since then may mean that today’s proportion could be higher.

The review cited a study by FHWA that estimated a savings of 1.72 gallons of gasoline for each telecommuting day based on the data from the 2001 National Household Travel Survey.

### ***Voluntary travel behavior change programs***

Voluntary travel behavior change programs are aimed at changing the behavior of travelers without changing the options available to them [40, 41]. These programs fall under two broad categories: mass communication campaigns and travel feedback programs. The latter use feedforward information such as travel diaries to encourage participants to examine their travel behavior; they also use feedback to convey the consequences of travel behavior changes. Travel feedback programs are usually directed toward households, although they are used in workplaces and schools.

Studies cited in the research on voluntary travel behavior changes show that VMT reductions of 5% to 8% are attainable through these strategies. They are most likely to be effective where traffic is seen as a problem, public transportation is available, local government and transit agencies provide support, walking and bicycling infrastructure exists, and local employment, shopping, and service destinations are available and accessible; these tend to be urban areas. These types of programs have, however, been used with effect in suburban areas as well.

## Land use strategies

The following land use related policies were addressed by the research for SB 375:

- Residential density
- Distance to transit (transit access)
- Land use mix
- Network connectivity
- Regional accessibility
- Jobs-housing balance

### *Residential density*

Research on residential density [1, 2] found that higher densities are associated with lower VMT. But a review of existing studies found that the average elasticity of VMT with respect to residential density ranged from -0.04 to -0.12, indicating that increasing residential density alone is not an effective means of reducing VMT. Evidence in the literature suggests that regional access to jobs is a more effective means of reducing VMT than density alone; hence, an area with high residential density located close to jobs would probably show a greater reduction in VMT than a high residential density area located farther away from jobs.

The review noted two methodological issues that are most important in the land use - travel literature, both of which can affect the relationship between residential density and VMT. First, there is the self-selection effect where persons might choose to live in high density settings because they seek to drive less; hence, density would only provide living places for persons who seek to drive less. An issue is therefore whether there is a sufficient supply of higher density neighborhoods to meet the demand of persons who seek to live in those neighborhoods. If so, building more such high density neighborhoods would not reduce VMT. But if there were a shortage of higher density neighborhoods (relative to demand for such places), building higher density neighborhoods would reduce VMT, even if the only effect were from persons choosing where to live.

Second, the review cited research that the effect of land use on travel is characterized by thresholds. For example, Boarnet et al. [5] found evidence that within small neighborhoods (a mile or less from end to end) residents can have as much as a five-fold difference in walking trip generation rates and differences as large as 30% in car trip generation rates. Those travel differences are associated with differences in land use characteristics within the small neighborhoods and persist even after controlling for differences in individual and household characteristics. These differences can be obscured by regional averages.

### ***Distance to transit (transit access)***

A review of the effect of residential distance to transit stations [42, 43] found that household VMT decreased from 1.3% to 5.8% for every mile closer to a transit station. But the review also noted that policies that increase access to transit by reducing distances to transit are generally implemented as part of a larger package of land use and transportation measure. Hence, it is difficult to isolate the effect of transit access alone. Also, results from the literature are highly dependent on transit service levels, local land use patterns, and location of the particular area studied within the region.

The review noted that distance from transit to the destination is highly important in mode choice behavior, and may outweigh the effect of residential distance to transit. But the review found no studies that quantify the destination distance effect.

### ***Land use mix***

Land use mix refers to the combination of different land uses within a given area or even vertically within the same building. The review of land use mix [34, 35] looked at several definitions of land use mix including the following:

- Ratio of jobs to residents at the neighborhood level (i.e. census tracts, census block groups, or ¼ mile radius areas)
- Variety and balance of land use types within a neighborhood (entropy)
- Vertical mixing of uses and floor space dedicated to different use types
- Number of retail and commercial uses within a given distance (typically ¼ mile) of residences
- Number of walking destinations in a neighborhood

The review found that the elasticity of VMT with respect to land use mix measures ranged between -0.02 and -0.11. But the review also noted that only one of the studies reviewed accounted for self-selection: i.e., persons who travel less may be more likely to live in mixed-use areas. The study did cite an independent national review that found that there was still an independent role of land-use mix in reducing VMT.

### ***Network connectivity***

Research on network connectivity considered the quality of the connections that link each of the points in a community with one another [16, 20]. Subdivision ordinances have often set standards that encourage street networks with low connectivity. Hence, the structure of residential street networks has evolved over time from grids to networks dominated by cul-de-sacs as shown in Exhibit 1 below.

**Exhibit 1 Evolution of Residential Street Networks**

	Gridiron (c. 1900)	Fragmented Parallel (c. 1950)	Warped Parallel (c. 1960)	Loops and Lollipops (c. 1970)	Lollipops on a Stick (c. 1980)
Street Patterns					
Intersections					
Lineal Feet of Streets	20,800	19,000	16,500	15,300	15,600
# of Blocks	28	19	14	12	8
# of Intersections	26	22	14	12	8
# of Access Points	19	10	7	6	4
# of Loops & Cul-de-Sacs	0	1	2	8	24

Source: Southworth and Owens in Southworth and Ben-Joseph [33].

Connectivity not only determines the directness of the connection between one point and another, it also determines the number of possible routes between one point and another. Other factors being equal, greater connectivity would imply shorter travel distances and therefore lower VMT.

The policy brief cites five studies of effects of increases in connectivity on reduction in VMT. Measures of connectivity included the following:

- Number of 4-way intersections within 1 mile of the household
- Number of intersections within 1 mile of the household
- Road density (lane miles per square mile)
- Percent of intersections that are 4-way
- Proportion of neighborhood blocks that are quadrilaterals
- Percent of intersections that are not dead ends

Results from the studies were mixed. Some studies showed decreases of between 0.06% to 0.59% in VMT for every 1% increase in connectivity, but one of the studies showed an increase in VMT associated with an increase in one of the connectivity measures.

Although the results are mixed, overall they indicate that increased connectivity can reduce VMT. A co-benefit of increased connectivity is reduced walking and biking distance, not only for walk and bike trips themselves, but for access to transit.

Several U.S. cities have changed their subdivision ordinances to promote greater connectivity. For example, Eugene and Corvallis in Oregon have maximum block lengths of 600 feet with requirements

for pedestrian connections at least every 300 feet. Several cities in North Carolina have adopted requirements based on the ratio between intersections and street segments. Some communities have restricted cul-de-sacs. Berkeley and Davis in California have increased pedestrian and bicycle connectivity by constructing a bridge over and a tunnel under a freeway.

### ***Regional accessibility***

Regional accessibility can be roughly defined as the average difficulty in traveling to jobs and other activity opportunities within a region. Most studies reviewed in the policy brief [17, 21] were concerned with job accessibility, defined as number of jobs weighted inversely by travel time or travel distance to the jobs. The studies showed on that on average the elasticity of VMT with respect to accessibility ranged from -0.05 to -0.25.

### ***Jobs-housing balance***

The studies reviewed by the policy brief [4, 24] used several different measures of jobs-housing balance including the following:

- Ratio of employment to population within a 3.1-mile radius of each TAZ centroid
- Ratio of jobs to households within 7 miles of each TAZ
- Ratio of jobs in the same occupational category to persons with that occupation within a 4-mile distance

The review found that there was a statistically significant relation between jobs-housing balance and VMT. The elasticity of VMT with respect to the various jobs-housing balance measures ranged from -0.29 to -0.35.

Jobs-housing balance is related to both regional accessibility and land-use mix, although regional accessibility is intended to measure a broader range of travel opportunities than just work travel. And jobs-housing balance is typically measured on a smaller scale than regional accessibility.

## **LEAST-COST PLANNING/INTEGRATED TRANSPORTATION PLANNING**

Least-cost planning – later designated “integrated transportation planning” – is a method that provides for comprehensive evaluation of all effects of transportation system alternatives. The following are the elements of integrated transportation planning [10, 30]:

- **Consider a full range of alternatives.** This includes both demand-side and supply-side alternatives. Most transportation studies consider only a limited range of alternatives, which limits at the outset the amount of information that planners can provide to policymakers.
- **Provide a consistent valuation of all effects.** All effects, including all social costs and benefits, must be accounted for. In particular:

- Effects should be monetized wherever possible and incorporated into a benefit-cost analysis.
- Effects that cannot be converted into monetary units should be quantified to the maximum extent possible.
- Effects that cannot be quantified should be stated qualitatively and compared (e.g., community barrier effects from a surface-level freeway).
- **Analyze effects of uncertainty on ranking of alternatives.** Uncertainties are present in all aspects of planning, including travel forecasts and valuations of costs and benefits. Determining sensitivity of ranking of alternatives to uncertainties that are present provides insight into the robustness of the rankings.
- **Engage the public throughout the process.** Public participation is often engaged at the end of the planning process, which limits public input and prevents the public from having a say on which alternatives are considered in the first place. Early public participation also allows the public to “buy in” to the planning process early on and become partners with planners and decision makers, rather than adversaries.
- **Analyze equity effects.** Alternatives will have different distributions of effects on different communities. Analysis of equity effects enables planners to provide information to policymakers on who gains and who loses for any particular alternative.
- **Monitor the system.** System monitoring provides essential feedback to the planning process on how well alternatives that are implemented actually perform. This information can guide analysis and evaluation for future planning efforts.

Least-cost planning was mandated by the State of Washington for evaluation of transportation projects. Work in this area included development of a primer for policymakers [9], technical guidance on how to incorporate least-cost planning into current practice [11], and a case study of application of least-cost planning to system-wide transportation alternatives [8].

While least-cost planning dates back to the mid-1990, it is a tool that has been used that quantifies effects including social costs and benefits and has potential to inform some of the SMF performance measures, particularly those related to equity and return on investment.

## PENNSYLVANIA AND NEW JERSEY DEPARTMENTS OF TRANSPORTATION

PennDOT and NJDOT developed Smart Transportation guidelines to address the cycle of growth requiring wider roadways, which encourages more growth, and so on [28]. Smart Transportation builds upon the concepts of context-sensitive solution—designing a roadway to fit its environment—by adding the concepts of network connectivity and access management. It encompasses six main principles:

1. Tailor solutions to the context—Contexts consist of community, environment, financial, land use, and transportation. Rather than the traditional engineering approach of

designing a roadway to the speed that most drivers would to travel at, the Smart Transportation approach is to use roadway design techniques to create a design operating speed appropriate for the context.

2. Tailor the approach—All roadway projects have their unique elements that should be considered during planning and design.
3. Plan all projects in collaboration with the community—The DOTs need to work with local officials and citizens to plan roadways that balance the community’s livability, business, and access needs with the state’s interest in regional and statewide mobility. Local governments are responsible for “sound land use planning,” which includes developing a network of streets that serve local trip needs, rather than relying on the state highway as the travel corridor for all types of trips.
4. Plan for alternative transportation modes—The needs of all modes must be considered when planning and designing roadway projects, recognizing that there may be trade-offs between the mobility needs of motorized vehicles and those of non-motorized modes.
5. Use sound professional judgment—Design guidelines are not a substitute for good professional judgment and sometimes design exceptions will result in the best outcome.
6. Scale the solution to the size of the problem—Some solutions may provide considerable benefit at relatively low cost, while not completely achieving an objective, while another solution may provide the last increment toward achieving an objective, but at relatively high cost. Constructing a high-cost, low-benefit solution may not be the best result.

PennDOT has expanded on these principles with ten Smart Transportation themes:

1. Money counts
2. Understand the context; plan and design within the context
3. Choose projects with high value/price ratio
4. Enhance the local network
5. Look beyond level-of-service
6. Safety first and maybe safety only
7. Accommodate all modes
8. Leverage and preserve existing investments
9. Build towns not sprawl
10. Develop local governments as strong land use partners

The Smart Transportation principles are incorporated into the roadway and land use planning guidance and have been incorporated into a number of New Jersey's and Pennsylvania's other transportation-related functions.

### North Carolina Sustainable Communities Task Force

North Carolina DOT is participating in a Sustainable Communities Task Force within the State Department of Environment and Natural Resources that was established in 2010 North Carolina General Assembly legislation. The goal of the initiative is to plan for healthy and equitable development without compromising natural systems and the needs of future generations. [26, 27]. In 2011 the Task Force awarded 9 grants between \$10,000 - \$50,000 that provided supplemental funding for projects including integrated transportation and land use studies, non-motorized transportation planning projects, and development of a form-based code that incorporates smart growth, sustainable, and new urbanism principles.

## APPENDICES

### INTERVIEW NOTES:

#### *Jeffrey Ang-Olson*

Jeffrey Ang-Olson was the lead author of the EPA Guide to Sustainable Transportation Performance Measures [47] as well as co-author of the Smart Mobility Framework.

The EPA guide to sustainable measures is not recommended necessarily for all studies. It just provides examples of measures that have been used at the regional scale. Not all measures will translate to a corridor level.

The concern about VMT per capita is the following: we could forecast that more drivers will be going faster and emissions will be going down due to reduced congestion. But if VMT goes down, congestion will get better and there will also be a reduction in adverse environmental effects. All bad effects (pollution, GHG) go down if VMT per capita goes down.

We should be looking at not just pedestrian and bike mode shares. We need to count pedestrians and bikes. There was an NCHRP project on how to forecast bike volumes, which is still ongoing. For example, we should measure how many cyclists there are in the corridor and how that will change.

Bike and pedestrian measures are very challenging to actualize. There are no good data on bicycle and pedestrian activity, so it's hard to know what is going on. Jeffrey suggests possibly conducting a travel survey targeted at bike and pedestrian travel, plus possibly some special counts (screenline, on bike facilities); for example, we could conduct counts on the Iron Horse Trail.

MTC has encouraged local governments to collect bike and pedestrian counts as part of the national bike and pedestrian project where data are collected nationally on same day. MTC may have some of these data.

For transit accessibility, SANDAG used that as a measure in their long-range plan. MTC also used it. One needs a good model to look at transit accessibility. Measures might include how many persons live around a transit stop; or how far one can get via transit within 30 minutes; or how many jobs one can get to by transit within 30 minutes.

There are approaches in the Highway Capacity Manual for multimodal level of service (NCHRP report 616 [7]).

Jeffrey also suggested trying to use some measures that cannot be done for the whole corridor for reasons of data or resource availability. This would at least establish a precedent for using these

measures. Perhaps we could try computing these sample measures for a few sample areas up and down the corridor.

There have been few attempts to weight different measures into a composite measure such as benefit/cost. MTC and a handful of other MPOs do it, but it's hard to find good examples.

The example in the EPA guidebook on Tampa for corridor-level planning is worth noting. They used all types of measures; transit, sidewalk, etc. For example, how much of the corridor has bike lanes; sidewalk facilities; pedestrian overcrossings

There may be a role for qualitative metrics that can't be quantified.

We need to push to get some incremental progress on better performance metrics. If we can include 1 or 2 new measures, we would be doing well.

Regarding emissions: total emissions will go down in future years because of cleaner vehicles. Perhaps we should be looking at per capita emissions, or VMT per capita emissions that would get at alternatives to driving; if more people driving and non-auto mode shares going down; need another metric than just gross emissions; because vehicle speed effects will dominate emissions metric; not doing enough on non-auto modes

### ***Marlon Boarnet***

Dr. Marlon Boarnet is Director of the Graduate Program in Planning at the University of Southern California. He has done extensive research on the relationship between urban form and transportation.

Boarnet advises don't think in terms of performance measures per se. It's a tough issue. On the one hand, we have LOS and similar measures, but these measure the system and don't give much insight into the people and community; LOS tells you about the roadway and can help you to make inferences, but not a direct measure of the individuals

There is a whole literature and thinking on quality of life: multimodal transport, active transportation, how transport weaves into life, etc. This often gets lost in traditional performance measures.

Which performance measures are important will vary from place to place. For example, Riverside may be more concerned with mobility; but San Francisco may be more concerned with safety in street crossing in front of house. Hence, performance measures should be cognizant of the local context. One has to know what the performance measures are going to be used for.

Boarnet's research in South Bay looked at things like number of walking trips per person, trip capture within localized neighborhoods (a very common measure), looking at local neighborhood travel. He looked at non-auto travel in neighborhoods.

A problem is that data don't exist for small areas. Travel surveys give only small sample of neighborhood travel. If one wants a better picture of a small area, one usually has to do additional surveys targeted at the area.

Environmental effects are very important such as air quality, and GHG emissions.

One needs a way to get at some of the intangibles. In Los Angeles he looked at communities severed by transportation facilities, which is hard to develop a quantitative measure for.

The issue is that we need a way to incorporate the values people place on literally removing infrastructure and making land availability greater. But this works against traditional performance measures because it reduces mobility. Traditional performance measures may favor large infrastructure projects; but communities may want to remove infrastructure.

Boarnet raised the possibility of a complete streets type of argument: more livable streets. But other agencies (state and regional) may balk at this. But we still need to figure in community perceptions and desires. The difficulty is that some measures may move in opposite directions; e.g., if want to remove portion of freeway, the travel models would show a decrease in LOS; need to work with communities to find out what performance measures are important to them. Some communities would say they want livability over reducing congestion. We need to allow the community or constituency to see how they would weight different measures against each other.

How would performance measures be used in the decision making process? This begs the question of what is the decision process and who are the decision makers. One may even propose to have local communities decide on what is important. Or we may want to go one step further; propose performance measures and have communities say what they do and don't value; determine which measures are open to local input and which are not. State and regional agencies may place limits on what communities can do in this regard. This may be a two-step process: 1) communities articulate their choice on performance measures, 2) determine what is dictated by state and regional agencies. Then try varying the weights on the different values.

Categories in SMF performance measures may make a lot of sense. It's important to get a sense of multi-modalism; existence value; also broad quality of life; benefit-cost is good to have in there as a performance measure. The main concern would be how to put those elements together because some elements will move in opposite directions. One may weight by context, by inputs, even an environmental justice component; e.g. emissions that affect low-income communities who are close to facilities; e.g., particulate emissions.

It would be useful to see how far the community can go in pushing state and regional agencies on how to vary the performance measures according to local conditions.

Recent work by Boarnet indicates that transportation is getting increasingly local and neighborhood oriented. This is partly being driven by local sales tax measures for transportation; e.g., Los Angeles

has an aggressive rail program. Within some neighborhoods he is seeing some variations. Funding sources are getting increasingly local.

Whatever performance measures we come up with, it's important to remember that this is not the 1960s. We're no longer into; not a national highway building project. Our policies are becoming the opposite. A problem here is that there is not a consensus on objectives or funding sources.

State and local agencies will therefore need a way to work within that realm and what roles they want to play and where they want to go. One extreme is that the state and regional agencies set the rules on what is acceptable. The other is where the community has all the input into the performance measures.

Data and tools will be difficult. For some things such as walk and bike mode split the data sources are very weak. Boarnet used NHTS, which used geocoded information for walk and bike in the SCAG area but hasn't gotten far enough. There is too small a sample sizes for small area analysis, so special data collections are needed such as special surveys, and screenline counts.

Pollutants present similar difficulties. One can interpolate from regional monitors, but how effective is this in determining local concentrations of pollutants? We may need to measure concentrations locally; e.g., near source monitoring, walking survey. This would cost on the order of \$50,000 - \$100,000 but it may not be sensible to do all the time.

We have poor modeling capability for walk and bike trips. Traditional mobility measures such as LOS can be gotten from travel models. But at the sub-regional level, say the South Bay area, which has 1M people, we might be able to mine some data in NHTS and the statewide travel survey. Hence, we could do some good work with walk and bike data. Boarnet recommends we think about this because it would take a lot of analysis; the models won't work at all; we would have to deal with the raw data.

How do we forecast impacts? That's where the models run into trouble. We have to find a way to go beyond what models provide. Maybe we need to use expert assessment because the models are too constrained.

The policy briefs for ARB on SB 375 could be informative in this regard. But the briefs are only as good as what the literature had. All the SB 375 papers looked at was VMT, but they could be used to pull out something more; for example, the briefs provide useful information on transit. The pedestrian and bike briefs may allow inferences about what would be reasonable predictions for pedestrian and bicycle use.

We do almost no post-project evaluation. Boarnet is currently working on a study to do pre and post evaluation of the Los Angeles Expo line. They collected 7 days of travel data using experimental and control groups; they are now doing an after opening collection and are still about a year away from publishing results. In concept, if we could do before and after evaluation we could build a large enough library of projects as well as informing performance measures that are hard to forecast

## **Ginger Dykaar**

Ginger Dykaar is a planner with the Santa Cruz County Regional Transportation Commission. She is currently working on an update of the regional transportation plan

Santa Cruz is using the STARS performance measures as a basis for their regional plan update. They now have a set of draft performance measures that will be finalized by 2014. There are 3 goals and 10 targets. Goals are the following:

1. Improve people's access to jobs, schools, health care and other regular needs in ways that improve health, reduce pollution and retain money in the local economy.
2. Reduce transportation related fatalities and injuries for all transportation modes.
3. Deliver access and safety improvements cost effectively, within available revenues, equitably and responsive to the needs of all users of the transportation system, and beneficially for the natural environment.

Each goal has an associated list of targets. Examples of targets are the following:

- Increase number of people within a 30-minute bike, walk, or transit trip to key destinations.
- Reduce per capita fuel consumption 5% by 2035 (ARB directive); hold steady at 0% increase in 2020
- Economic benefit target: Reinvest in local economy by a certain amount of money per year; if VMT is reduced, spend less money on fuel. This will increase the amount of money that can go into the community; assume that 75% of fuel cost savings go into the community.
- Travel time reliability: Multimodal level of service; improve TT reliability for vehicle trips and modal access
- Increase HOV mode share

It has always been a problem to get data for the performance measures. They have been able to get some. Targets were chosen based on an estimate of the data available so they can monitor progress. Santa Cruz doesn't have the data resources that large MPOs have.

The agency is using GIS tools and working with the STARS team. They have a consultant doing GIS work for them and updating the regional travel demand model. SWITRS data are used for collisions; other sources include census data and the California statewide travel survey for the regional model update.

The goal on reduction of GHG means that no capacity increasing targets would be advanced if it results in increased GHG emissions. The county also has a list of strategies that they developed; certain strategies that say that if they advance the mobility targets, but make sure that there is no induced demand with a capacity increase.

Mobility was big push in past plans; now access is the goal; LOS isn't discussed in any goals. Travel time reliability and speed consistency are important.

There has been no direction from the commissioners on weighting different performance. The way they'll score the projects is to see how an individual project advances the goals in the grouping of goals. At a later time when bringing projects together they will determine how to prioritize packages of projects into different scenarios and will develop themes behind the scenarios. These are outcome-based themes; e.g., improving safety as a theme; improved access as a theme; maintenance of roadways as a theme. They want to see what different packages offer as far as targets go and how they will advance the numerous targets.

The new measures were well accepted by commissioners and public. But the level of detail can be overwhelming for the public, People more interested in their own projects. It's hard for people to step back and see the big picture. The county did a number of surveys: one was on goals and targets. They got a lot of agreement on the three goals; 90% agreement. They also conducted a workshop with 20 people; there were 400 responses to the survey.

There are two different ways to use targets: 1) to prioritize projects, 2) measure system performance over time. The county hasn't figured out all details. Some things may change as the plan progresses.

Planners developed walk shed (2.4 mph walk speed), a bike shed (5 mi distance), and 10 key destinations for 30 min access. This is challenging because people may not agree with the definitions of key destinations. One difficulty is that because the of 5-mi bike shed, the bike shed covers a lot of the county, so it doesn't narrow down effects of improvements.

There is also the issue of how to measure changes over time. They are using a GIS analysis for the baseline; e.g., looking at points on the map for the pedestrian access shed to determine percent sidewalk coverage. Some data are available in GIS, other data are from Google Street View. They took % sidewalk coverage; if it was less than 100%, they reduced the walk rate, and therefore the access measure. For bike facilities: if there were no bike facilities, the rate of bike movement was assumed to be slower; so there would be a smaller bike shed around key destination points;. For transit they assumed a 5 min walk to the bus stop, a 5 min walk to destination, and a 20 min transit ride, they used census data with access sheds to determine how many people live within area.

The analysis will use the regional travel demand model to get VMT. They will also use post-processing to take into consideration other issues (e.g., 8 Ds) and come up with a final estimate of VMT.

For prioritizing strategies, they look primarily at reductions in VMT for each strategy, then prioritize those projects that do the best job. They use EMFAC for GHG, and fuel consumption, estimates, and therefore the amount of money that can go into the local economy. For reliability and multimodal LOS, they will go to list of strategies where multimodal LOS can be increased.

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### ***Peter Hurley and Kelly Rodgers***

Peter Hurley and Kelly Rodgers worked on the development of the Sustainable Transportation Access Rating System (STARS).

The discussion centered on several of the performance measures that we recommended for the I-680 pilot area.

On safety measures, STARS measures injuries and fatalities rather than crashes because these are the most significant safety issues. The number of injuries and fatalities is also a good measure for equity because these particularly affect disadvantaged populations and modes: elderly, disabled, bicyclists, pedestrians, etc.

Hurley and Rodgers are working with a jurisdiction where one of the measures to be considered is a bicycle and pedestrian path. They want to project mode share for this measure. Working with the MPO in the area they developed a bike model that's better than most available models. There is better network modeling for bicycle. They also use the idea of a low-stress network analysis: more persons are willing to bicycle on low-stress facilities such as non-arterials and other facilities with lower traffic levels and roads with lower traffic speeds. Low-stress network analysis is being used in San Jose. It is also being used in Portland to project bicycle use. Analysis of route directness also helps in creating a more robust bike and pedestrian analysis for the area

In Santa Cruz, they are looking for reducing the number of short trips that hop on and off SR-1 by providing alternate routes on local streets.

The bike model that Portland uses, now in the pilot development stage, may or may not be transferable to another areas. The model uses demographic data specific to the area. Portland may be willing to share the model. The issue is whether the model may be relevant to other areas. The model was populated with a more recent household travel survey and further demographic information on the area.

Economic benefits should incorporate private as well as public costs; e.g., costs of vehicle ownership, operating, and maintenance. When doing an analysis for a bus corridor in Clark County they found that private costs are very high, in fact, much higher than public costs. Travel time savings are soft costs; costs such as fuel costs are hard costs. Accounting for private costs such as fuel costs incorporates the cost of owning and operating a vehicle in the economic analysis and shows up in an analysis of ridesharing vs. a capacity expansion alternative.

Travel time reliability and speed consistency are also important.

Fuel consumption a "heavy lifter" performance indicator because it is a surrogate for a number of things: e.g., keeping money within the community, reducing pollution and GHG emissions, increased physical activity is one of those: keep \$\$ in community, reduce GHG emissions, increased physical activity from use of non-motorized modes, improved vehicle flow.

STARS is an outcome-based approach to analysis. The idea is to use adaptive management to make changes along the way as you continue to monitor the system.

Regarding land use, this can be an important issue. Hurley cited the LUTRAQ study in Portland as showing how land use measures can be highly effective in reducing the need for highway capacity expansion. Hurley believes that in our studies it may be worth raising the issue of a mixed strategy of land use and transportation including support for sustainable growth. There can be significant economic benefits: reducing VMT, reducing fuel consumption, and reducing congestion by shifting to trips that are more local and therefore shorter. It might appeal to politicians to promote smart growth as a way of locating more jobs in Contra Costa County. Perhaps there is an opening to talk about job creation and walkable neighborhoods and downtowns.

One method for looking at land use changes is a visual preference survey. This was developed by someone out of Princeton and used in “new urbanist” developments. The idea gets beyond the concept of “development”; it lets people decide what it is they want. From past work in this area it is clear that people tend to prefer moderate density, walkable development, greenery, and low traffic speeds. In this regard, Hurley suggested looking at average trip distance as a measure. For example, this is what they are trying to do in Santa Cruz: encouraging shorter trips on arterials rather than longer trips on freeways.

On social equity, Hurley commented that the corridor analysis in Clark County looked at locations where transportation disadvantaged persons tended to travel: e.g., VA hospitals, shelters, schools; destinations of higher use for transportation disadvantaged. Looking at where these persons tend to travel may be another way of looking at the equity issue rather than looking at the home end.

### 1.1.1 Jonathan Levine

Jonathan Levine, is Professor of Urban Planning at the University of Michigan. He has been doing research on accessibility vs. mobility.

The core argument that mobility metrics ought to be replaced by accessibility metrics. Accessibility does not necessarily mean proximity. It is made up of three components:

- Mobility
- Proximity
- Connectivity (phone, fax, internet)

These are means to accessibility, which is the proper end. This is based on idea that idea of transportation isn't movement, it is access. The paradox is that we tend to evaluate outcomes through mobility metrics, but implement alternatives that degrade access because origins and destinations get spread apart. We remain stuck in terms of highway level of service and use this to guide land use planning. We need to get beyond this.

Levine's metrics focused on the first two components above. It is still difficult to figure out how to integrate connectivity. Hence, for now, the focus is on the tradeoff between mobility and proximity. We know how to make places where surface travel is fast, but where origins are far apart. Where origins and destinations are closer, surface transportation tends to be slow

There are three major families of metrics:

- Based on cumulative opportunities
- Gravity based
- Utility based logsum

Levine's work was mostly on the first two of these.

Cumulative opportunities are great because they are comprehensible; easy to explain; e.g., how many jobs can be reached within 30 minutes by car or transit; how many restaurants are within a 15-minute walk, etc. The weakness is that they draw an arbitrary line and are insensitive to opportunities that fall outside the boundary; e.g., an opportunity 2 min away is same as one that is 29 min away; but one that is 31 min away doesn't count at all

Levine has tended to use gravity based accessibility metrics, which seem to do a good job. This has been used in a research article comparing accessibility in a number of urban areas in North America [25].

The key to using these measures in practice is that we need to remember that we mustn't assume transportation or land use are fixed. We have to allow both of those to vary. If we don't assume land use can vary, we are limited to mobility measures.

We want to evaluate alternatives for accessibility: i.e., either changes in land use or changes in transportation that improve accessibility. We can also talk about change in access if we go high tech (e.g., improved high-speed internet access). If we start from land use –; e.g., a developer wants to build 1M sq ft facility near downtown – what are accessibility effects of that development? We need to know the land use changes (the developer in this case), transportation changes (e.g., do a traffic impact analysis to assess the needed roadway changes); so now we have a land use change and a transportation system change. With that we can forecast changes in accessibility using cumulative opportunities or gravity models

If we're talking from a transportation change standpoint we need to forecast transportation system changes and their effects on land use change. For example, if we build a freeway, we can forecast transportation effects, but we also need to forecast the land use effects of transportation system changes. We need to do both sides of the system. Hence, we need to use integrated transportation and land use models. Once we have those tools, we have the data we need and can use our gravity metrics to evaluate accessibility.

Our traditional mistake is to assume that land use won't respond to transportation system changes. This is the Achilles heel of traditional planning.

It's important to focus on evaluation measures because evaluation metrics rule the roost. We talk about lofty goals, but when push comes to shove we use LOS for our decision making on transportation and land use. The lofty words that we give to accessibility get lost to mobility. Hence, embodying accessibility metrics is very important.

Levine has been looking for practice-based examples of using accessibility metrics in Portland, and the Netherlands. In both cases, they talk about it, but in terms of formalized metrics, very little has been done.

Maybe as a placeholder we can include land use changes as something to look at but may conclude that land use change is zero. But at least we need to go through the step of considering land use change; so at a future date when there is a more integrated transportation plan, there is a framework to look at this.

Think about land use effects. Transportation changes may be too small to affect land use. We may say that we need a package of transportation system improvements (a plan) that isn't just a tweak here and there, but something that is of a sufficient scale so that land use would be affected. On the other hand, in some cases the transport changes may be too small to affect land use.

Some feedback from a colleague in the Netherlands: B/C practice now is more mobility based (time savings) than accessibility based. As a thought experiment, think of a transit improvement that spurs a lot of development around it. The improvement ends up not saving anybody time because it triggers more investment downtown. We need accessibility based benefit/cost analysis. For example, logsum metrics can provide a basis for multimodal accessibility measures by showing the change in traveler utility based on accessibility.

### 1.1.2 Douglas MacDonald

Douglas MacDonald was Secretary of Transportation for the State of Washington from 2001 – 2007. He initiated the Gray Notebook [48], which one of the earliest examples of performance measure reporting by state DOTs. Washington State DOT now reports on a number of performance measures [50] and also provides links to other state and national web sites on performance measure reporting [49].

The Gray Notebook came about because in 2000 there was a transport funding crisis in Washington due to passage of an initiative that repealed the vehicle excise tax, a major transportation funding source. The governor appointed a blue ribbon commission to figure how to deal with the situation. The issue that was identified was to figure out how to get more accountability out of the state DOT. Hence, they needed performance measures. There were many studies of performance measures, but there was a lot of redundancy and futility in many of the measures.

MacDonald's experience with directing the water and sewer agency for the Boston region had led to the development of performance measures for what really counted in terms of what the agency was supposed to deliver to its users: clean drinking water. This led to developing a suite of performance measures that directly addressed the issue, and led to a significant change in investment policies by the agencies. In particular, rather than investing in mega-facilities such as treatment plants, the emphasis shifted to improving pipelines.

When MacDonald came to Washington State DOT he realized that what was needed was to put the department back on course by rebuilding public confidence. Performance measures were seen as a strategic option to do just that.

Rather than spending time on further studies of performance measures, MacDonald promised to have a first set of performance measures published within 60 days. He thought it would not be productive to first spend several years to develop suites of performance measures, especially since the department already had a lot of data. Instead, he directed his staff to figure out what they already had and get it out to the public. Performance measure development was seen as an iterative process where the measures would be modified as experience was gained.

The first Gray Notebook was based on experience with corporate ethics: the first page was about safety to underscore fact that safety is first priority of the department. The first Gray Notebook, produced 4 – 5 weeks later; had to do with worker safety and traffic fatalities.

For the 6 years MacDonald was at the agency was there added on more and more things were added to the Gray Notebook. This has now become the premiere example of tools for state performance reporting.

The biggest benefit has been that it has persuaded the media and the legislature that the state DOT has a commitment to transparency on what is going on in the agency, which is a huge dividend. That was the strategic purpose of the starting the project in the first place.

Later editions of the Gray Notebook were divided into 2 sections: one on capital projects (cost vs. budget, actual vs. scheduled time, etc.) and one on system performance. The "beige" pages: provide accountability reporting on capital projects. It tracks revenue projections vs. actual spending. Originally spending outran revenue capacity. It was therefore important to track and make clear what the actual vs. projected revenue sources

On uses side, the Gray Notebook tracked projects and provided an early warning system. It's easy to report on completed projects but harder to report on projects in trouble. And any agency is going to run into problem on about 10% of their projects, not due to negligence or inattention, but due to other factors outside the control of the agency. The credibility of the transportation program is as dependent on clarity and transparency as it is on ribbon-cutting ceremonies. The agency developed a watch list of issues that arose: e.g., an unexpected geotechnical situation. Everything was reported to

the state legislature. Full disclosure of what was going on was highly helpful to Washington State DOT credibility with the legislature.

On the operating side the notebook reports on what the agency is doing. They reported on a conventional things like ferry on-time, change in VMT, fatalities, injuries, pedestrian fatalities, bike injuries, etc.; they also very early on addressed congestion

Problems arose between the DOT and the Texas Transportation Institute's annual Urban Mobility Report [44]. This report, used as a national barometer of congestion, reflected unfavorably on Seattle, which was ranked very high in terms of congestion, and led to a lot of concern there. MacDonald had to deal with the publicity from press releases about the report. He got his staff together and asked what they could do that to get Seattle down to 10<sup>th</sup> or so place from 2<sup>nd</sup> or 3<sup>rd</sup> place. Staff answered that can't do anything about it because it isn't reporting what's really going in in Washington, but just reporting measures based on computer models and V/C ratios. The report didn't reflect things like Seattle's HOV lanes, good transit, etc., in the rankings. Nothing that the DOT could do would affect Washington's ranking in the TTI report because all measures come out of V/C ratios.

MacDonald asked why Washington should be prisoners of a metric that isn't relevant to Seattle's needs. It's advertised to the public that the TTI report was somewhat relevant to congestion, but it's just an extension of V/C extrapolation. Washington and several other states cancelled their investments in the TTI report and publicized it, saying the report didn't reflect reality. TTI responded quite by modifying their method of computing congestion. Every year they now make improvements; include such things as operational improvements (e.g., ramp metering) and transit.

Washington DOT also started to look at non-recurrent congestion, which accounts for 55% of the delay on the system. This was seen as a huge opportunity: instead of huge outlays on capital projects for recurrent congestion they could get a better return on investment from operational improvements such as a service patrol. This was implemented with a lot of publicity, and then reported on in the Gray Notebook. The Gray Notebook has since evolved into an annual congestion report, which also reports on travel time reliability and incident clearance. And the state's policies shifted in emphasis to operational techniques like ramp metering and incident clearance. Washington DOT arbitrarily set 90 minute incident clearance as a reporting threshold.

The lessons from MacDonald's experience are the following:

- First, there is an iterative process to performance measurement development. One can't just come out and announce a suite of performance measures because one doesn't know it all at the start. And the system is going to change. Hence, performance measures are a learning process, and the learning has to be done by the agency. As performance monitoring and reporting goes on, an agency will to refine some measures, and abandon some measures, and add other measures. The important thing is not the graph but the intelligence that goes behind the graph. Performance measures show not so much how the system performs, but how the agency is being run attention to results. The agency should use numbers as a learning technique to modify its direction.

- Second, they are a learning process. They need to be used for management and for communication. MacDonald found it amazing how many times he found that performance measures were used but not communicated
- Third, an agency has to measure things that are relevant to what it does. For example, the issues have now shifted travel time reliability, reflecting what is important to people. One of the things that has happened in Washington is that now measures of 90% travel time reliability are reported and communicated to the legislature.

Non-traditional performance measures are difficult to develop and implement.

Regarding “non-traditional” measures such as environmental stewardship, GHG, mode split, etc., the issue is what the agency can do about it. For example, VMT may go down, but that may be due to economic conditions or gas prices, which are outside the control of the agency. Washington State DOT fell into this trap. In 2010 travel time reliability improved because of the recession. It’s very easy to hang yourself on measures that are outside your control. So you need to be concerned with what you are measuring.

Regarding smart mobility, it’s great branding, but an awkward marriage. A lot of times you’re talking with people who agree with each other on what to do. Smart Mobility Framework measures look good, but some measures say “to be determined”. But the issue is what can you measure? This has been very problematic. To MacDonald, fossil fuel consumption is a critical measure. That’s the metric that determines almost everything else with regard to emissions; it’s also a derivative of things like mode split. Transit may not be “green” if you’re running around a bunch of empty buses. As SOV energy use becomes more efficient, and transit runs a lot of empty buses, actual per seat mile fossil fuel consumption of transit may not compare well to SOV fuel consumption. So, fossil fuel consumption is more important than VMT, and it’s easier to track than VMT

Some measures deal with sprawl and meta-measures of land use density and how transport system affects density. Sprawl is not easy to define, but the Brookings Institution has developed measures of “land conversion”; but these are not popular because they bring into the spotlight how regulate land use and the tax system. These measures look at land conversion first and not “walkability”. A lot of the “walkability” and “bikeability” measures are contrived. It’s hard to devise a measure of walkability that makes any sense, or that can be communicated to the public.

MacDonald believes that environmental performance measures should also be concerned with the relationship between transportation and water; e.g., issues such as stormwater runoff from freeways. He advises pressing for identifying the connection between the way the transportation system is organized and operated and toxic runoff from transportation facilities. This is very important for linking transportation and environmental issues. It is also linked to issues such as habitat protection, etc. By the way, regarding habitat protection, a lot of habitat restoration in transportation has failed.

Everybody wants to address disadvantaged populations. But the problem is how to define the things to measure this.

### 1.1.3 Susan Zielinski

Dr. Susan Zielinski is managing director of the SMART mobility program at the University of Michigan.

Accessibility is highly important. But we usually end up measuring transportation instead of access to needs.

A lot of measures we have are individual measures, e.g., GHG emissions. If one looks at GHG emissions saved by a certain mode, something like a Zip car won't rate very high. But if one looks at a *system* of transportation that links all modes, the picture changes; e.g., car share may be the last link that lets you leave a car at home and use an alternate mode. Hence, seamless connectivity is what is important. But it is hard to measure effect of these types of policies on GHG emissions.

We therefore end up using measures that can show – or model – the effect on reducing GHG emissions. We don't really have good measurements for the transportation system as a whole, and that is something we need. If we look at global urbanization, we won't have everyone in a self-driving electric vehicle or using other forms of clean technology. We need to look at seamless connections between modes.

Many policy solutions look at things piecemeal. Need to look at attitudes of persons toward transportation, what makes them behave the way they do, also safety and security. We need to look at what goes into mix of individuals' decisions about leaving car at home, psychological factors, etc. A lot of measures are measuring the wrong thing or not measuring the suite of things people really look at when making travel decisions.

Indicators can be damaging if specified at the outset. There is a high value to involving all stakeholders at beginning to come to an agreement on what is to be done and what indicators will be used, and how to discipline people who don't make measurements (Healthy Cities)

There needs to be some spaces where there are opportunities for organic learning and creativity and exploration and failure. When we get into measurement based obsession we're losing out on a lot of greatest innovations. For example, many things can put in place with few resources that are very high value.

We often measure things by money, so we tend to apply measurement only when economics is involved. But we still need to build spaces for innovation. We don't have measures drive the exploration of new alternatives. Many things we in our lives now would not be here if they had been subjected to measurement early on. Hence, measurement is not the only thing in evaluation.

Another issue is that we're afraid to measure some things because of the economy or there are other sacred cows; for example, promoting electric vehicles. Sometimes there is measurement and evaluation where shouldn't be, and no evaluation where there should be.

Transportation is not flat, like other industries. There are underlying imperatives. We only put things in if they won't hurt the economy. This foregoes a lot of opportunities, like addressing environmental needs. Lot of times we're making the tradeoffs in advance of even considering some alternatives; we're pre-screening. This is the "level playing field" argument: not to prejudge what we are going to evaluate.

Transportation is not just the car, especially in the worldwide scheme of things.

On measurement side, one of her worries is that we measure what we can afford to measure; so get a lot of information on the car but not on walkability; for example, who is to know what is in the interest of the urban poor? There are measurements we don't make, and therefore these considerations don't enter into decision making. Hence, for example, we have information on car safety, and know that good cars save lives; but we don't think about pedestrian and bike injuries due to cars; so we end up not doing enough about pedestrian and bike safety

What are levers for moving in certain directions? How do we get funding for certain measurements [non-traditional, in this case]. The main concern is what outcomes are.

A few people have said lately "you can't manage what you can't measure". The problem with indicators is there certain things you can't measure and that shouldn't be managed. But we still sometimes try to measure things that can't be measured

Another example of what we don't measure: averted trips and trips made shorter by smarter planning; e.g., telecommuting; or avoiding traveling to the grocery store by growing food at home. We only measure movement, so these other measures get lost. Hence, it might be interesting to measure how much VMT was saved by people not taking trips; 1 day a trip telecommuting would be 20% reduction in trips.

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