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MTI MINETA TRANSPORTATION INSTITUTE

Toward a Guide for Smart Mobility Corridors: Frameworks and Tools for Measuring, Understanding, and Realizing Transportation Land Use Coordination

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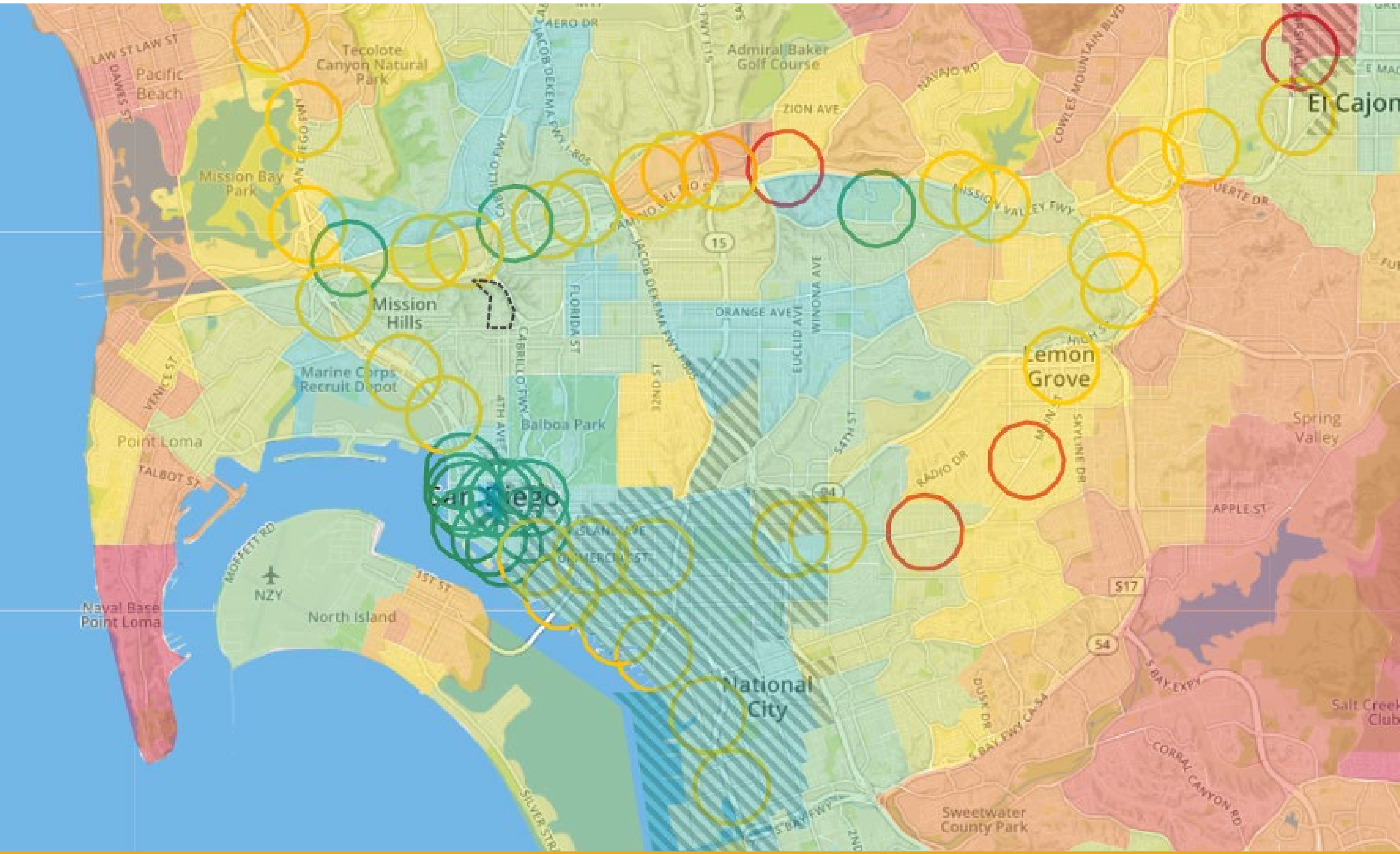

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REPORT 20-54

TOWARD A GUIDE FOR SMART MOBILITY CORRIDORS: FRAMEWORKS AND TOOLS FOR MEASURING, UNDERSTANDING, AND REALIZING TRANSPORTATION LAND USE COORDINATION

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16. Abstract

The coordination of transportation and land use (also known as "smart growth") has been a long-standing goal for planning and engineering professionals, but to this day it remains an elusive concept to realize. Leaving us with this central question -- how can we best achieve transportation and land use coordination at the corridor level?

In response, this report provides a review of literature and practice related to sustainability, livability, and equity (SLE) with a focus on corridor-level planning. Using Caltrans' Corridor Planning Process Guide and Smart Mobility Framework as guideposts, this report also reviews various principles, performance measures, and place typology frameworks, along with current mapping and planning support tools (PSTs). The aim being to serve as a guidebook that agency staff can use for reference, synergizing planning insights from various data sources that had not previously been brought together in a practical frame.

With this knowledge and understanding, a key section provides a discussion of tools and metrics and how they can be used in corridor planning. For illustration purposes, this report uses the Smart Mobility Calculator (https://smartmobilitycalculator.netlify.app/), a novel online tool designed to make key data easily available for all stakeholders to make better decisions. For more information on this tool, see https://transweb.sjsu.edu/research/1899-Smart-Growth-Equity-Framework-Tool. The Smart Mobility Calculator is unique in that it incorporates statewide datasets on urban quality and livability which are then communicated through a straightforward visualization planners can readily use.

Core sections of this report cover the framework and concepts upon which the Smart Mobility Calculator is built and provides examples of its functionality and implementation capabilities. The Calculator is designed to complement policies to help a variety of agencies (MPOs, DOTs, and local land use authorities) achieve coordination and balance between transportation and land use at the corridor level.

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EXECUTIVE SUMMARY

The coordination of transportation and land use (also known as “smart growth”) has been a long-standing goal for planning and engineering professionals, but to this day it remains an elusive concept to *realize*. Leaving us with this central question -- how can we best achieve transportation and land use coordination at the corridor level?

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Specifically, this report presents the following:

- A review of the literature and practice related to sustainability, livability and equity
- A brief review of Planning Support Tools (PSTs).
- A discussion of measurement and action/policy guidance frameworks, as well as how they can be applied through the use of an accessible online tool, the Smart Mobility Calculator to corridor level planning.
- A discussion of the development of a decision making framework, using the Caltrans’ Smart Mobility Framework Implementation Project as a case study.
- This report shows how the Calculator can be used in a variety of situations towards better transportation/land use coordination, especially at the corridor level.

Such a planning and evaluation framework must be able to: (1) help understand what is important to measure and analyze in current conditions and future scenarios; (2) help create context-sensitive and inclusive processes to guide policy actions; and (3) screen, prioritize, and mediate strategies in support of transportation and land use coordination—which could be defined as increasing a diverse and complementary set of choices and opportunities for individuals to pursue toward the achievement of their desired quality of life.

I. INTRODUCTION

The umbrella term Transportation Land Use Coordination (TLC) is a widely recognized approach for achieving what is often referred to as “smart growth” (Cervero 2001; Moore, Thorsnes, and Appleyard, 2007; Appleyard et al. 2016a; Appleyard et al., 2019). However, in the absence of substantial institutional changes to transportation and land use that allows stakeholders to work in a truly coordinated fashion, we are left to seek methods with data, performance measurement, and policy guidance frameworks to achieve more holistic TLC approaches. As discussed in Appleyard et al. (2014, 2016, 2019), transportation agencies, such as Caltrans, can best achieve sustainable, livable, and equitable outcomes when they work in concert with others, especially local land use agencies. Therefore, a major focus of this report is to help guide staff in state DOTs, regional MPOs, and local land use authorities to develop frameworks to *measure* performance of corridors in terms of their transportation/ land use coordination (TLC), be able to *understand* what those measurements mean, and then guide actions, decisions, and policies toward *realizing* stronger TLC.

Here are some givens that may further our understanding of what is happening. First, as a transportation agency, Caltrans, and most other DOTs work at a much broader spatial scale than most land use agencies—primarily at the regional/corridor levels. Second, as a transportation agency, Caltrans interacts, either directly or indirectly, with many other agencies and can engage, at some level, with their core activities, whether it be land use, housing, public health, environmental quality, and/or economic development. Therefore, Caltrans is in an ideal position to reach out and work with the other agencies (as a sort of ambassador) toward realizing a higher level of coordination of a variety of government activities at the corridor level. A key opportunity is that Caltrans can offer a forum for coordinated governance at the corridor scale--a scale critical for the coordination of transportation and land use, around which agencies can work together. To this end, Caltrans and other DOTs need solid frameworks and tools to measure the TLC performance of urban environments, as well as the ability to understand what the measures mean and then the ability to put that knowledge into practice. Caltrans has made significant strides toward TLC through its Smart Mobility Framework efforts. This work build on this work.

To help Caltrans and other DOTs work with and refine various measurement and policy guidance frameworks, this report builds on a variety of academic research from fields such as urban planning, geography, and operations research. As part of the development of the Smart Mobility Calculator, this report also draws on literature and practical experience related to planning support tools (PSTs).[1]

A key aim of this report is to bring the coordination of transportation and land use by the loosely organized collection of actors and agents (MPOs, DOTs, and local land use authorities, etc.) into coordination through new measurement and policy guidance frameworks to be applied through a variety of planning support tools (PSTs). To illustrate the applications of the various frameworks, this report uses the Smart Mobility Calculator (https://smartmobilitycalculator.netlify.app/), an online tool designed by the authors to make key data easily available to all stakeholders so they can more readily make coordinated decisions. Absent a major restructuring of our transportation and land use institutions, and the scales on which they operate, adopting new frameworks to *measure* and *understand* transportation and land use coordination (TLC) is the first step toward *realizing* it.

II. UNDERSTANDING SUSTAINABILITY, LIVABILITY, & EQUITY

Sustainability, livability, and equity are long-standing societal objectives, but they remain elusive concepts in policy and practice. And while a number of related performance measures and tools have been developed over the past two decades, there appears little progress toward a generally accepted set of measures that can inform planning and policy decisions.

This report provides a review of literature and practice to help inform the preliminary development of a measurement, evaluation, and policy guidance framework based on sustainability, livability, and equity. The review will give context to the concepts and foundational measurements and calculations of the Livability and Smart Mobility Calculators.

The report then works toward integrating Smart Mobility principles, concepts, and performance measures in accordance with the Smart Mobility Framework (SMFs) as described in Caltrans' *Smart Mobility 2010: A Call to Action for the New Decade* (Caltrans, 2010) as well as the *2020 Corridor Planning Process Guide* (Caltrans 2020). Both these projects were conducted in response to several state-level mandates to reduce greenhouse gas emissions from the transportation sector, as well as to enhance California's environment, economy, and equity (the 3 Es). The analysis and recommendations in this chapter are also based on a joint project between Caltrans, the South Bay Cities Council of Governments (SBCCOG), the Los Angeles County Metropolitan Transportation Authority (LA MTA), and SCAG to implement the SMF in a planning project for the South Bay Cities area of LA—this project merges SMF place types and Metro's Accessibility Clusters, as presented in LA MTA's Metro Countywide Sustainability Planning Policy (CSPP). A key goal of the work presented in this report is to inform and assist Caltrans' efforts on a variety of issues, including complete streets and corridor planning, and with regional Sustainable Communities Strategy (SCS) as part of California's climate action initiatives.

HISTORY OF THE TERM "SUSTAINABLE DEVELOPMENT"

The concept of sustainability as applied to human settlements and activities was first popularized in the 1970s with the publication of *The Limits of Growth* (Meadows et al. 1972) wherein the authors argued that a "sustainable" condition of ecological and economic stability was possible if significant changes were made to industrial and developing economies. Though the idea of sustainability had long been discussed in terms of biological and ecological systems, its application to human settlements was new, but it soon became common in academic and popular publications (see Beatley 1995; Wheeler 2000; Jepson 2001). The "Brundtland Report,"[2] published in 1987, provided the definition of sustainable development that has been most widely cited and used ever since:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (World Commission on Environment and Development 1987, p. 43)

This definition has been criticized as being anthropocentric (i.e., overly concerned with humans) and subjective (how does one objectively measure "needs"?). Many other definitions have been offered, but most of them have been problematic in fostering agreement on what specific concepts or indicators to measure and how to do so in a way that is widely accepted (see Wheeler 2000 and Jepson 2001 for more detailed discussions of the history and definition of sustainability). Despite the definitional problems, there is growing consensus that sustainability has three main components: economic sustainability, environmental sustainability, and socially equitable sustainability.[3]

DEFINING URBAN SUSTAINABILITY

According to the 1998 NSF Report on Urban Sustainability,[4] in order to understand urban sustainability, it is important to examine the process of urbanization within the context of dynamic and complex social, economic, political, and ecological processes producing sustainable or unsustainable urban landscapes and outcomes. The report goes on to suggest that research should be designed around an extensive program of comparative case studies, focusing on long-term analyses of human–environment dynamics at selected sites. Therefore, while there are numerous ways of achieving sustainability, it appears that performance evaluation frameworks should be at the center of how different agencies can work together through their fostering of a common understanding of what the evaluations mean and what policy actions need to be taken.[5]

DEFINING LIVABILITY: THE TRANSPORTATION/LAND USE, SMART GROWTH, & LIVABILITY CONNECTION

For years, top researchers in urban and transportation planning have focused on developing effective strategies for transportation/land use coordination (TLC) and smart growth to achieve a wide range of goals associated with livability (Appleyard, 2005; Moore et al., 2007; Appleyard, 2011b; Cervero, 2003, 2001). In a 2001 speech to the Australian Planning Association, Robert Cervero described the fundamental elements needed to advance “smart growth,” directly characterizing this as the coordination between transportation and land use planning (Cervero, 2003, 2001). In 2005, Susan Handy published an article in the International Regional Science Review in which she reviewed recent research on the transportation and land use connection, which further tied TLC to smart growth (Handy, 2005). At its core, transportation and land use coordination (TLC) is an integrative concept that ties together access through both (a) mobility via transportation policy, and (b) proximity via land use policy (Cervero, 2000; Cervero et al., 1999; El-Geneidy and Levinson, 2006; Levine et al., 2012, 2009; Levinson, 1998; Wagner and Caves, 2012). Therefore, TLC can be viewed as a key component of best planning practices connected to the provision of access to “livability opportunities” (Appleyard et al., 2014; US EPA, 2016; Moore et al., 2007) and “smart growth” (Cervero, 2000) by both practitioners and academics alike. For example, in Chapter 11 of Wagner and Cave’s book Community Livability, Dr. Ruth Steiner establishes the EPA’s ten smart growth principles as a mainstay of livability planning operating through transportation and land use coordination. Along these lines, there is a strong resemblance between the six livability principles of the HUD/US-DOT/EPA Sustainable Communities Partnership (SCP), outlined in the next paragraph and the EPA’s ten smart growth principles (US EPA, 2016; Wagner and Caves, 2012).

However, in large part due to the institutional imbalances between the transportation and land use sectors (Appleyard, 2005, 2011; Appleyard et al., 2014; Moore et al., 2007), smart growth and TLC have been hard to achieve in the United States. To illustrate this point, the reader should recognize how the transportation sector, in comparison to the land use sector, has a powerful vertical public/private organization that can effectively coordinate technical expertise and programmatic knowledge to both fund and deliver projects, from road to rail transit. In contrast, land use decision making follows a much more complex, multifaceted, and loosely coordinated horizontal structure of actors including local governments, developers, real estate agents, financial institutions, community members, and advocates, with interests ranging from pro-smart-growth to not-in-my-backyard (NIMBY) sentiments. This mismatch, or imbalance, between the organizational capacity and wherewithal of these two sectors to deliver and coordinate their activities can be referred to as the transportation–land use imbalance and/or disconnect (Appleyard, 2005, 2011; Appleyard et al., 2014; Appleyard et al., 2019; Moore et al., 2007).

In response, this work endeavors to rebalance and re-integrate this disconnect through effective performance measurement frameworks and policy responses that elevate land use and urban design to be conducted at a more regional and corridor perspective, putting them on par with the scale at which we plan our transportation.

Frameworks for Evaluating Smart Growth, Transportation Land Use Coordination, Sustainability, Livability, and Equity

Research and practices focused on combining transportation land use coordination with livability reached an important milestone in 2009, when a comprehensive definition of livability was adopted by the Secretaries of Housing and Urban Development (HUD), the US Department of Transportation (USDOT), and the Environmental Protection Agency (EPA) through their Sustainable Communities Partnership (SCP). In 2016, a National Academies of Sciences project was completed that worked to better operationalize these six principles for measurement, analysis, and policy guidance through an online Smart Mobility Calculator and *A Livability Calculator for the Handbook for Building Livable Transit Corridors* (Appleyard et al., 2018, 2016; Ferrell et al., 2016). The Caltrans Smart Mobility Framework Principles are also provided (on the right). The similarities between all three are important to recognize. See Figure 1.

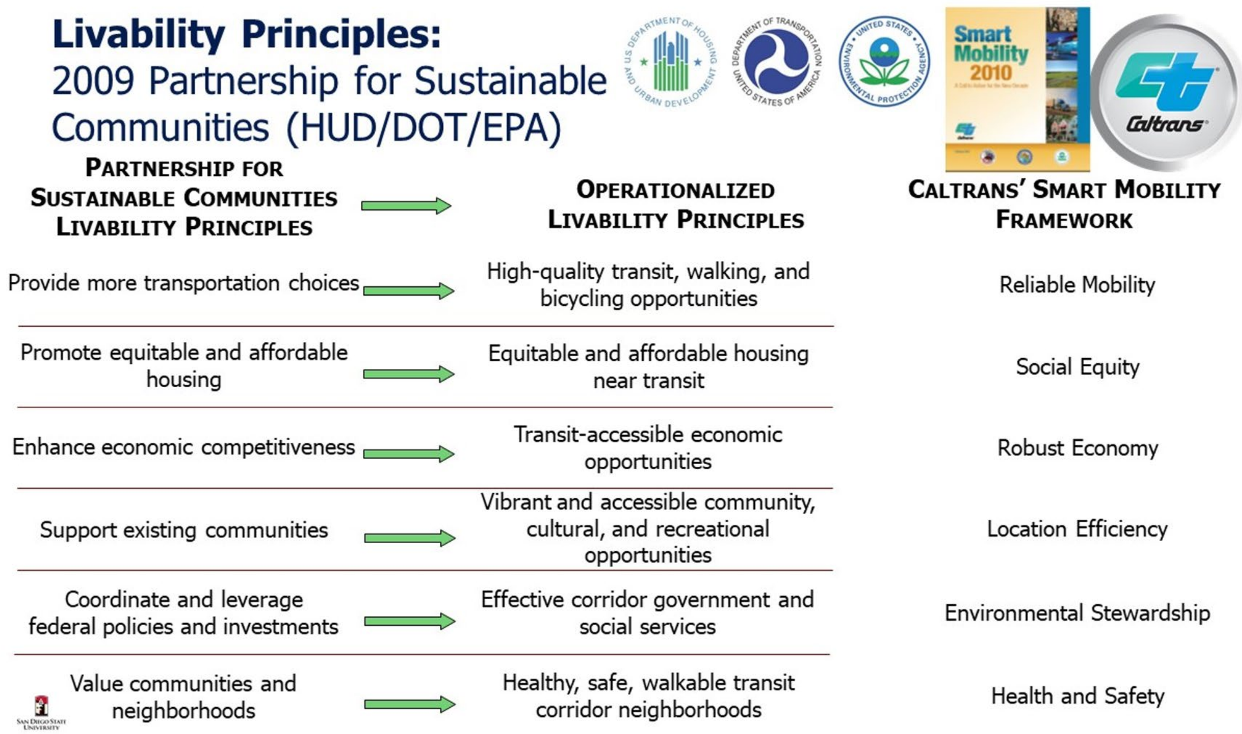

Figure 1. Operationalization of the Livability Principles of the 2009 HUD/DOT/EPA Partnership for Sustainable Communities

Overall, the detailed language reveals how federal and state officials, and arguably many other professionals, were combining concepts of livability with concepts of smart growth, and, by extension, transportation/land use coordination. From previous work, the authors developed a framework where the measure of urban quality, or transportation/land use coordination (TLC), is determined by what the authors refer to as “livability opportunities” (affordable housing; presence of jobs; and safe, accessible walkability) (Appleyard et al., 2014; Appleyard et al., 2016). These opportunities can then be converted into quality of life outcomes, which can include things like health, safety, social inclusion, emission reductions, and so on (Appleyard et al., 2014; Appleyard et al., 2016).

These findings are also consistent with other previous studies linking higher levels of built environment performance, in terms of smart growth and TLC, to health outcomes. For example, several articles find that more compact communities are associated with lower traffic collision rates (Ahangari et al., 2017). Other studies show a connection between transit service, ridership, and improvements in traffic safety (Litman, 2016; Stimpson et al., 2014). Additionally, scholars have examined the relationship between greater walking, bicycling, and transit access and increased public health benefits from greater physical activity (Frederick et al., 2018; Lachapelle, 2010; Lachapelle and Frank, 2009; Sallis et al., 2016). Another recent study by Hamidi et al. (2018) found that life expectancy was significantly higher in compact rather than sprawling counties in the US, but the causal mechanisms are still unclear. Finally, there are new studies indicating how more compact and multimodal built environments increase economic mobility (Ewing et al., 2016; Frederick and Gilderbloom, 2018).

DEFINING EQUITY: TOWARD AN EQUITABLE LIVABILITY AND SMART GROWTH

In measuring and understanding social equity, we need to first measure (a) the access to opportunities (jobs, schools, transport, etc.), (b) vulnerabilities (crime, education levels, quality of schools), and (c) determine whether there is an inequitable distribution based on socio-economic backgrounds to either the access to opportunities or exposure to these vulnerabilities. However, to enact policies, we likely will need an ethical framework to ensure livability achievement is equitable.

It is important to understand that what we value determines what we measure—what we measure determines how we understand problems. Therefore, what we value and measure determines the solutions that become physically manifest in our environments. So we need to examine what we value and how we measure, understand the problems, and then realize solutions. This is the domain of ethics. Therefore, rather than embracing one monolithic definition of livability, there is a need for a theoretical moral framework to measure, understand, and judge activities toward an equitable and just standard for livability achievement through a set of clear, concise, and easily applicable principles and approaches toward the realization of an ethical livability. In sum, we need livability ethics.

Upon review of all definitions of livability and smart growth (Appleyard et al., 2014; Appleyard, B. & Appleyard, D. 2020), the authors have defined ethical and equitable livability and smart growth as:

> People's easy and equitable access to opportunities they can readily pursue for their desired quality of life—
>
> Prioritizing the needs of society's less powerful and most vulnerable, placing highest value on people's humanity, at rest and in motion, and working to overcome any past, present, or future forces of oppression.

With this maxim in mind, and our methods for measuring and understanding social inequities outlined above, we can stand a better chance of realizing an equitable livability/smart growth. To achieve this, professionals will need to be prepared to mediate between livability pursuits in conflict to *prioritize the needs of society's less powerful and most vulnerable.*

SECTION CONCLUSION

In sum, these six livability principles, the operationalized principles, and the Smart Mobility Framework Principles all reflect normative best planning practices related to smart growth, new urbanism, and transportation and land use coordination (TLC). As measures of urban quality that follow these principles can hopefully secure a spectrum of livability opportunities, we can, in turn, achieve a range of sustainability, livability, and equity outcomes for a greater number of people (Appleyard et al., 2014; US EPA, 2016)—all key goals of this research.

III. BACKGROUND AND OVERVIEW OF PLANNING SUPPORT TOOLS (PSTS)

Before going into more detail about the Livability and Smart Mobility Calculators, this report first provides a review of the literature and practical applications of planning support tools (PSTs). Planning support tools (also called planning support systems) are computer-based applications that assist in urban planning activities by providing access to essential data, models, and spatial analysis methods (Geertman and Stillwell, 2004). These tools have transformed the ways planning is conducted by improving efficiency and reducing the complexity of planning-related tasks (Exner, 2015). Though impactful, planning support tools are not without their shortcomings. For example, a survey conducted by Vonk et al. (2005) suggests that a lack of awareness and experience with planning support systems is a significant hurdle for widespread adoption of these tools. Subsequent work by Vonk and Geertman (2008) recommends that planning support tools should emphasize accessibility to ensure that they are put into practice.

RELATED ACADEMIC WORK

To help Caltrans work with and refine various measurements and policy guidance frameworks, this work builds on a variety of academic sources from fields such as urban planning, geography, and operations research. Furthermore, as the authors are looking to exploratory web mapping applications, this project also aligns heavily with research on web GIS, geovisualization, and GeoDesign.

Along these lines, Jiang et al. (2003) provided an early demonstration of how Internet-based geovisualization applications can support planning-related decision making. More recently, scholars have shown how the rise of new data sources and GIS technologies has allowed for the creation of more powerful geovisualization and web GIS tools that allow researchers to model and explore urban environments (Yin, 2015). GeoDesign is also a new and exciting research and development area that employs an interdisciplinary approach combining GIS with urban planning to design projects at community, regional, and sub-regional scales (Steinitz, 2012). GeoDesign tools are often specifically geared toward improving sustainability in urban areas (Steinitz, 2012; Dangermond, 2010).

Finally, this project builds upon work in multi-criteria decision analysis (MCDA). The goal of this field is to create tools and strategies to help decision makers, planners, and policy makers better understand the potential outcomes of projects by revealing a wide variety of relevant factors for review (Malczewski, 2006). MCDA has been widely promoted as a scenario testing and design tool that guides decision making in order to attain more environmentally sustainable communities (Cinelli et al., 2014; Pohekar and Ramachandran, 2004). MCDA is often tightly coupled with GIS, as mapping tools and methodologies are proving essential in evaluating and understanding relevant criteria (Malczewski and Rinner, 2015).

A REVIEW OF PRACTITIONER PLANNING SUPPORT TOOLS TO HELP MEASURE, UNDERSTAND, AND REALIZE SUSTAINABILITY, LIVABILITY, AND EQUITY OUTCOMES

At the national level, both EPA and DOT have promoted tool development for specific uses in addressing measures of sustainability and livability. Several tools and frameworks have emerged from states and regional agencies, as well as from academic research teams, professional bodies, and international groups. Table 1 summarizes the tools and frameworks that are available to evaluate transportation and land use projects related to at least some aspects of sustainability, livability, and equity.

Table 1. Sample of Public Sustainability and Livability Planning Tools

Tools
East Tennessee's Regional Plan for Livable Communities Livability Dashboard. A website has been set up as an example of a Livability Dashboard to track scenarios and indicators linked to East Tennessee's Regional Plan for Livable Communities.
Transit Livability Assessment Tool (CUTR University of South Florida for FTA). The project tasks including cataloging potential measures for livability and creating a data collection plan. Other tasks include developing a livability index database, developing livability index scores, and developing a livability index dashboard. A final task is demonstrating the dashboard, measures, and applicability in practice.
A Composite Sustainability Index (Atlanta, GA). Considers multidimensional conflicting criteria in the transportation planning process and identifies the most sustainable (or least unsustainable) plan for predetermined objectives.
Envision (Harvard's Institute for Sustainable Infrastructure). Evaluates, grades, and gives recognition to the community, environmental, and economic benefits of infrastructure projects.
GreenLITES (New York State Department of Transportation). Expanded program includes rating systems, spreadsheets, and other metrics to assess projects, plans, and operations and maintenance programs, as well as regional programs.
Greenroads (Greenroads Foundation; developed by University of Washington researchers and global engineering firm CH2M Hill). A sustainability rating system for roadway design and construction. It is applicable to all roadway projects including new projects, reconstruction and rehabilitation (including overlays), bridges, or any other project in which a road is involved. Performance metric awards points to more sustainable practices during the design and construction phases of roadway projects
Illinois Livable and Sustainable Transportation (I-LAST) (Illinois Department of Transportation). Checklist of potentially sustainable practices is followed by a description of the intent of each category in the checklist and the rationale and measures of effectiveness for each item. Lists of source materials and additional background resources for each item assist in understanding and applying the practices.
Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) (FHWA). Web-based self-evaluation tool with three categories or criteria: project development, operations and maintenance, and system planning. Assigns each practice a point value (weight) according to its relative impact on roadway sustainability.
Least Cost Planning (Oregon Department of Transportation). Model for use as a decision-making tool in the development of plans and projects at both the state and regional levels. Livability, safety, equity, economic vitality, and environmental stewardship will be evaluated side-by-side with traditional considerations such as capital costs.
Model of Sustainability and Integrated Corridors (MOSAIC) (Maryland State Highway Administration). Tool employs a Microsoft Excel spreadsheet. Six categories of sustainability indicators: mobility, safety, socioeconomic impact, natural resources, energy and emissions, and cost. Includes more than 30 sustainability performance measures.
KeepSpace Project Assessment Tool (State of Rhode Island). Spreadsheet tool assesses: transportation choice and accessibility, housing choice and affordability, economic development, support of existing communities and designated growth centers, community character and collaboration. With optional weighting.
Sustainability Enhancement Tool (Texas Department of Transportation). Excel-based calculator that applies performance measures for sustainability at the highway corridor level; includes 12 performance measures.
Sustainable Transportation Access Rating System (STARS) (Oregon, Washington, California, and Nevada). A framework applies 29 credits organized into six categories: integrated process; access; climate and energy; ecological function; cost-effectiveness analysis; and innovation.

Tools
Sustainable Corridor Rating System (University of Delaware, Newark). Methodology for the development of rating systems for urban corridors and mobility-focused transportation systems.
CEEQUAL (Transnational). Online assessment tool scores project performance on management, environmental, and social issues.
Evaluative and Logical Approach to Sustainable Transport Indicator Compilation (ELASTIC) (United Kingdom). Framework for identifying and selecting a small subset of sustainable transport indicators.
Green Guide for Roads (Transportation Association of Canada). Initial framework includes 13 areas where sustainability practices can be applied, with a description of requirements and associated best practices or strategies. Applies to all types of roads in urban and rural settings and includes sustainability considerations such as improved compatibility and livability; universal accessibility; modal equity; conservation of resources; affordability on a full life-cycle basis; and environmental protection.
Urban.Access (Israel). Developed as an ArcGIS extension that can be used in urban regions worldwide where high-resolution geographic information system (GIS) data are available. Enables a detailed representation of travel times by transit and car and makes it possible to compare accessibility levels by transport mode.
ATC National Guidelines Systems Planning. Framework for route and link planning developed in Australia by Austroads Inc., 2009; assesses various routes and links in the process of road transportation planning.
Urban Social Vulnerability Index Tool. Developed by Robert Goodspeed, this tool is used to extend methods of social vulnerability analysis developed in the context of natural hazards to urban development.
IWR-APT (Assistance for Planning Teams). An online software program to help planners create, edit, analyze, and manage their study materials. The modules include: Risk Register, Decision Management Plan, Decision Log, Study Issue Checklist, and Smart Planning Deliverable Workflow.
Corps Risk Analysis Gateway. A website maintained by the Institute for Water Resources (IWR) for understanding the Corps model for risk analysis.

Sources: Adapted from CTC & Associates, TRIS

In addition to publicly developed resources, a number of scenario planning tools were evaluated by the research team, including Envision Tomorrow Plus (ET+), INDEX, iPlaces3, Urban Footprint, and Rapid Fire Models. Given the need for their application to involve interagency collaboration and public involvement, it was important to consider how adaptable and transparent these tools are.

Following the specific needs of the agency or agencies responsible, the underlying goal of the majority of these tools is to support better coordination of transportation and land use planning (Ramini, 2010). Many of these tools have a secondary goal of highlighting trade-offs between the dimensions of sustainability, livability, and equity.

Review of a Sample of Online Mapping Applications and User Interface

An important aspect of any planning support tool for greater inter-agency and public collaboration is that it have an accessible and easy-to-interpret geospatial (mapping) interface. Accessibility and ease of use is an important aspect of mapping systems and of the Smart Mobility Calculator, where the wide range of anticipated users (planners of all types, members of the public, policy makers) are not guaranteed to have previous GIS or mapping experience. Therefore, the authors conducted a review of useful online indicator tools with mapping interfaces.

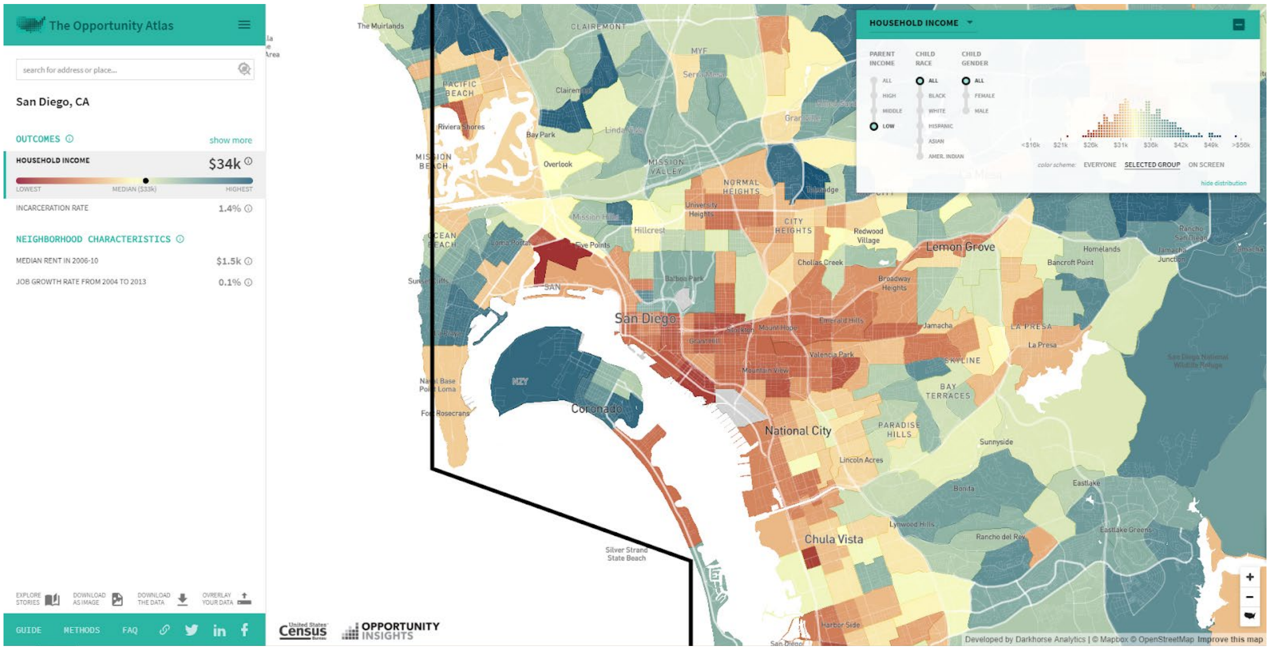

Figure 2. A Screenshot of the Opportunities Atlas, Produced by Opportunity Insights at Harvard University

Existing online mapping tools include websites such as the Opportunities Atlas, the California Healthy Places Index, and the Center for Neighborhood Technology (CNT) Housing and Transportation [H + T] Affordability Index. The Opportunities Atlas tracks adult outcomes for US census tracts where children grew up. For any given census tract, a variety of metrics can be selected and viewed for adults who spent their childhood (born between 1978 and 1983) in that tract. The map shows one metric at a time along a blue-to-red scale, with average and neighborhood characteristics appearing along the left side. The mapping tool is also able to calculate and graph statistics for only the area shown on the screen, rather than nationwide statistics. For more information on other tools, see the Appendix.

SECTION CONCLUSION

In reviewing these planning support tools, it was revealed that all had limited sensitivity to changing facilities for anything but single-occupancy vehicles and transit. Even the most basic auto alternatives such as pedestrian bicycle facilities were limited to changes in intersection density and measures of mixed-use entropy. Another limitation is that innovative transportation solutions and policies, such as person-sized-motorists (PSM, including e-scooters), neighborhood electric vehicles (NEV), car sharing, and bike sharing, are even less researched. While the authors reviewed the growing body of research on the effects of bicycle facilities on travel behavior, much work needs to be done to better incorporate the effects of these facility investments in planning processes.

Many scenario planning tools rely on research from Ewing and Cervero (2010), and on the work behind other tools, such as the MXD tool developed by Ewing et al. (2013), which relies on such measures as intersection density and a measure of entropy for mixed-land uses, which are really too coarse to truly understand what happens when new facilities are put in for bicycling, pedestrians, or emerging services, such as e-scooters and NEVs. Promising research to address these issues can be found in LA Metro's bike modeling project and research currently underway at SDSU's Active Transportation Research Center. This review helped inform the design of the interface of the Smart Mobility Calculator, especially in terms of the placement, design, and dynamic readout of the dashboard.

Building on the above. the next section presents a discussion of the use of the Livability and Smart Mobility Calculators, and how specifics on measures, frameworks and decision processes discussed up to this point will benefit the future of sustainability, livability, and equity for all Californians.

IV. LIVABILITY AND SMART MOBILITY CALCULATORS

New Tools for Measuring Understanding and Realizing Smart Growth for Sustainability, Livability, and Equity

INTRODUCTION AND BACKGROUND

This section provides a brief "walk through" of the development of a specific set of frameworks and tools by the research team designed to (a) help agencies evaluate the strengths and weaknesses of transportation land use coordination (TLC) and smart growth, and then (b) help determine the best policies going forward to realize a stronger transportation land use coordination and smart growth.

Transportation and Land Use Coordination (TLC) is a widely recognized approach for achieving what is often referred to as "smart growth." However, absent substantial institutional changes enabling transportation, land use, and other disciplines to truly work in a coordinated fashion, we are left to use data, performance measures, methods, and policy guidance frameworks to realize TLC.

In response, this section discusses the development of two planning support tools (PSTs) and their underlying frameworks and measures to help an array of stakeholders better understand the sustainability, livability, and equity performance of urban places so they can make more informed decisions about how communities and regions should grow and evolve, now and in the future.

The Livability and Smart Mobility Calculators

The Livability Calculator for the *Handbook for Building Livable Transit Corridors* (http://bit.ly/LTCHanbook) builds on the foundations of the Six "Livability Principles" of the 2009 HUD, US DOT, and EPA Sustainable Communities Partnership by operationalizing them through a focused set of transportation, land use, and quality of life metrics. As these are essentially re-statements of EPA's ten smart growth principles, this is an effective planning support tool for measuring urban quality, since it relates to such concepts as smart growth and new urbanism, as well as the associated sustainability, livability, and equity outcomes.

The Livability Calculator assesses smart growth and livability performance by operationalizing the six HUD/EPA/US-DOT principles, as shown in the radar graphic in Figure 3 below. The operationalized principles are as follows:

1. High-quality transit, walking, & bicycling opportunities,
2. Healthy, safe & walkable transit corridor neighborhoods,
3. Vibrant & accessible community, cultural & recreational opportunities,
4. Accessible social & government services,

5. Transit-accessible economic opportunities, and

6. Mixed income housing near transit (this currently supports the social equity principle, which measures housing affordability and income diversity).

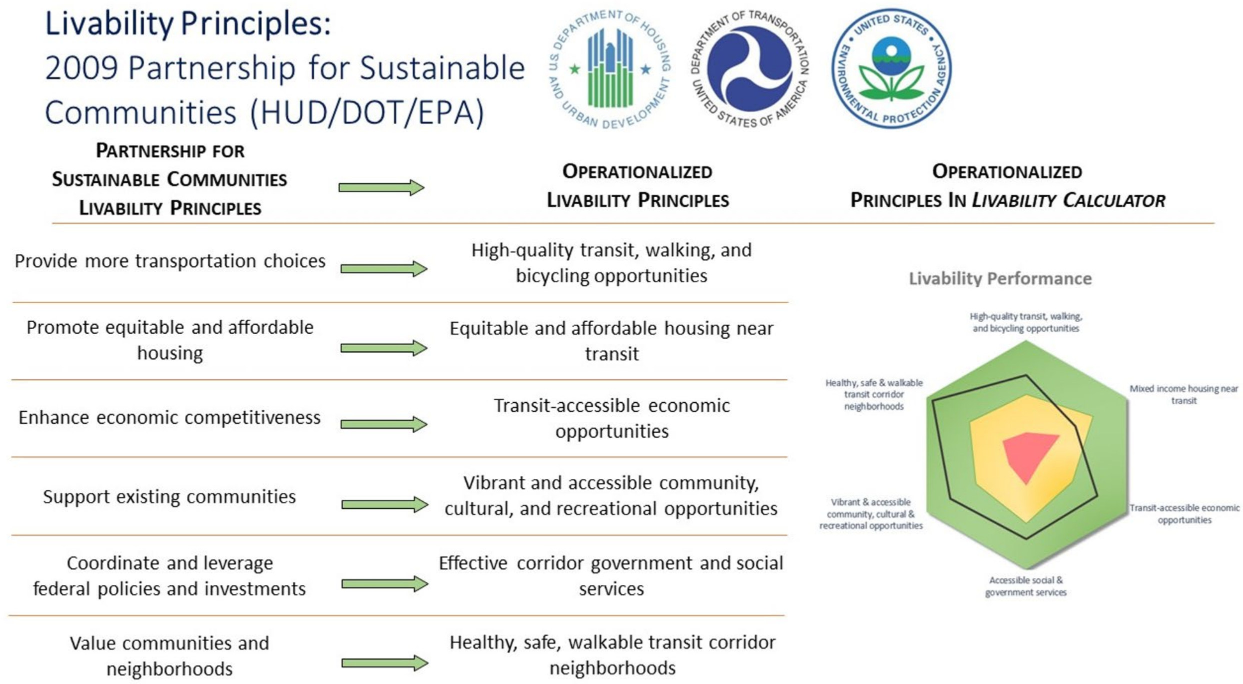

Figure 3. Operationalizing the 2009 Livability Principles of the HUD/US-DOT/EPA Sustainable Communities Partnership

Livability as Access to Opportunities to Improve/Maintain One's Desired Quality of Life

As discussed earlier in the section on Livability Ethics, smart growth/livability performance is suggested by the authors to be framed by measuring people's equitable access to *livability opportunities* to improve and maintain one's desired quality of life. Such frameworks help guide the use of measures that then provide guidance on policy decisions. Therefore, the Livability Calculator currently assesses urban quality by operationalizing the Six HUD/EPA/USDOT principles, as shown in Figure 3 above. From left to right the original Livability Principles are listed, followed by the operationalized Livability Calculator Principles, and then an example of a radar graphic readout from the Livability Calculator itself which lists the operationalized principles as well.

The above framework and principles can be built upon to determine what to measure and how these measures guide policy. In the development of the Handbook and Calculator, the authors gathered an extensive array of geo-spatial data to explore the relationships between the measures of urban quality and a host of quality-of-life outcome measures (see Table 2 below). For this study, a California statewide database of built environment characteristics and sustainability performance metrics was created for 8,043 census tracts and 23,212 census block groups.

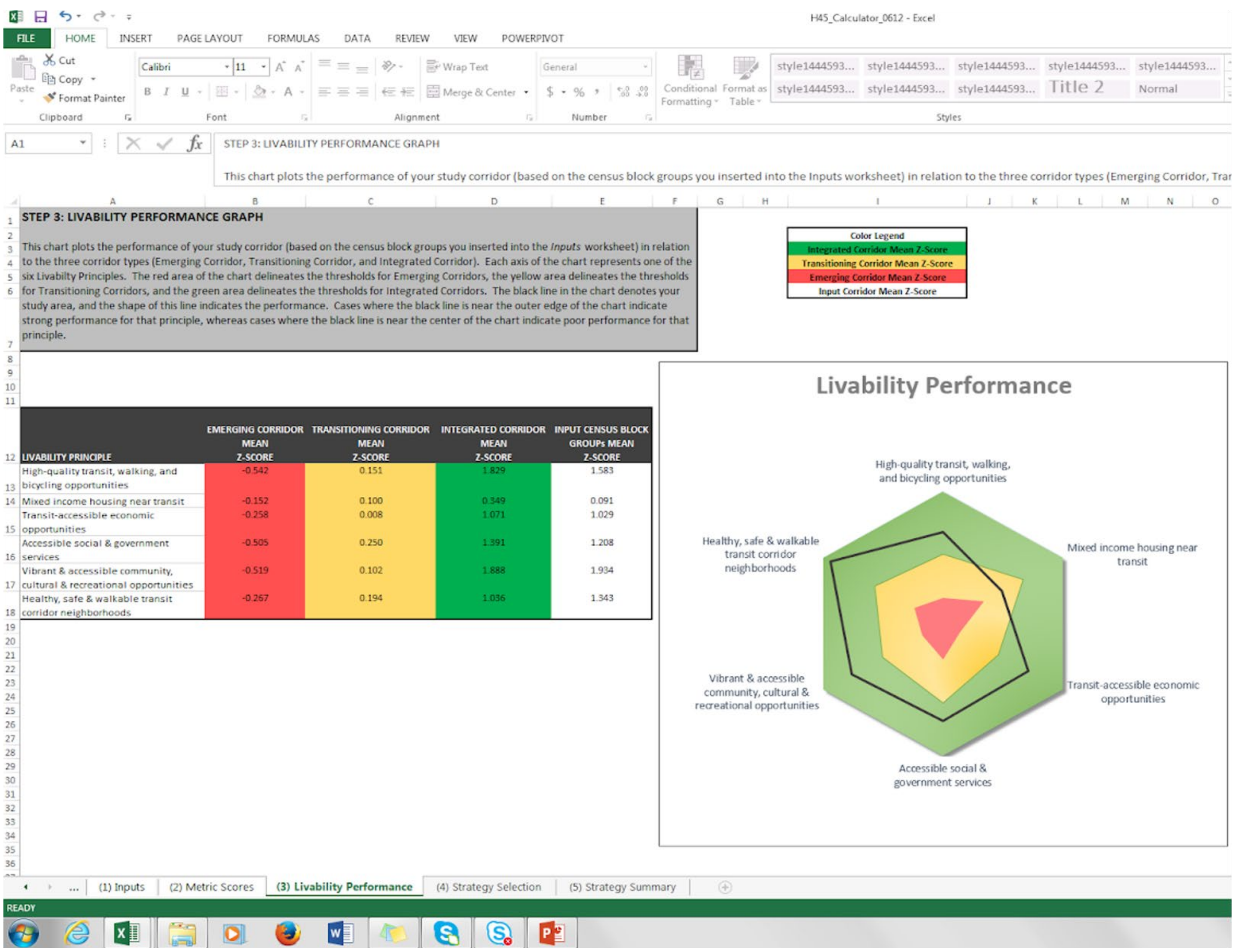

Figure 4. Livability Calculator for the Handbook for Building Livable Transit Corridors

Source: to download both the Livability Calculator and the Handbook for Building Livable Transit Corridors http://bit.ly/LTCHanbook

Table 2 shows the twelve metrics in the Livability Calculator of the operationalized Livability Principles of the 2009 HUD/US-DOT/EPA Sustainable Communities Partnership.

Table 2. The Twelve Metrics of the Livability Calculator: Operationalizing the Livability Principles of the HUD/USDOT/EPA Sustainable Communities Partnership

Transit Corridor Livability Principles	Metric	Data Source(s)
High-quality transit, walking, and bicycling opportunities	Transit jobs accessibility	EPA's Smart Locations Database (SLD) 2013 D5br: Jobs within 45-minute transit commute, distance decay (walk network travel time) weighted
	Transit service coverage (aggregate frequency of transit service per sq. mile)	SLD D4c: Aggregate frequency of transit service within 0.25 mile of block group boundary per hour during evening peak period

Mixed-income housing near transit	Housing unaffordability (percent of income spent for housing)	HUD's 2012 Housing Affordability Index Data Set (HAI) hh_type1_: housing cost as a percent of income for the regional typical household, defined as mean HH size for region, median income for region, average number of commuters per HH for region
	Income diversity (variance from regional median household income)	National Historical Geographic Information System (NHGIS), 2010 Census ID B19013: Coefficient of variance of block group median household income compared to either the metro area or the state median; closer to zero means less diversity, closer to one means more
Transit-accessible economic opportunities	Jobs density (employees/acre)	SLD D1c: Gross employment density employees (jobs)/acre on unprotected land, 2013
	Retail jobs density (retail employees/acre)	SLD D1c_Ret10: Gross retail employment density employees (jobs)/acre on unprotected land
Accessible social & government services	Transit ridership balance of flows	Transit agency route/line data Inbound (to CBD) daily boardings/inbound daily alightings
	Health care opportunities (health care employees/acre)	SLD D1c8_Hlth10: Gross health care (8-tier) employment density employees (jobs)/acre on unprotected land
Vibrant & accessible community, cultural & recreational opportunities	Population density (population/acre)	SLD D1b: Gross population density (people/acre) on unprotected land
	Access to culture & arts (# corridor entertainment employees/acre)	SLD D1c_Ent10: Gross entertainment employment density employees (jobs)/acre on unprotected land
Healthy, safe, & walkable transit corridor neighborhoods	Pedestrian environment (intersection density)	SLD D3bmm4: Intersection density in terms of multimodal intersections having four or more legs per square mile
	Pedestrian collisions per 100,000 pedestrians	Transportation Injury Mapping System (TIMS) 2010 Pedestrian collisions per 100,000 pedestrians

SMART MOBILITY CALCULATOR: OVERVIEW

(https://smartmobilitycalculator.netlify.app/)

Building on the earlier work on the Livability Calculator, described above, Dr. Appleyard and his student research team developed an online Smart Mobility (SM) Calculator (https://smartmobilitycalculator.netlify.app/) using similar data and metrics as was gathered for the development of the Livability Calculator. (For more information, see the website https://transweb.sjsu.edu/research/1899-Smart-Growth-Equity-Framework-Tool.) One of the goals was to make the visualization of these data and calculations more accessible for key stakeholders (practitioners, members of the public, and politicians) to use toward analysis and policy guidance for a number of different transportation and land use coordination issues, including climate action planning, corridor planning, and new housing initiatives (such as SB 50 and SB 827). The SMC can also be used for new environmental regulations under SB 743, which allows for streamlining of significant developments in areas that are 15% below regional averages for per-capita vehicle miles travelled (VMT) as opposed to level of service (LOS). The SM Calculator can even be used to determine the performance of future transportation scenarios, including but not limited to those future scenarios related to autonomous vehicles (AVs) and Mobility as a Service (MaaS).

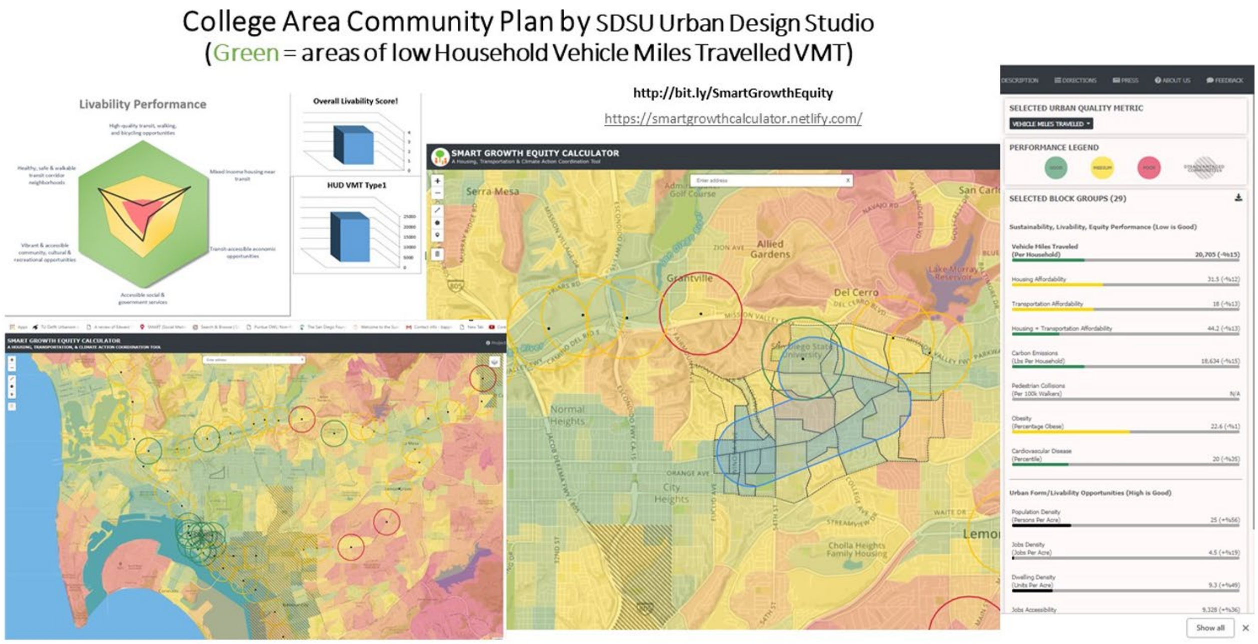

Figure 5. An Example of How the Performance Radar Graphic from the Livability Calculator Can be Merged with the Smart Mobility Calculator

Upon hovering the mouse cursor over an area, one can see percentages of VMT per capita displayed on dashboard on the right, showing how much an area is above or below the regional average. Along these lines, the SM Calculator can also be used for new housing initiatives. For example, it can show the areas around transit that could potentially be up-zoned (per bills like SB 50); the SM Calculator shows the areas that are in close proximity to transit, while also showing the location of disadvantaged communities (per SB 535) in the hatched areas. The disadvantaged communities overlay is key to being able to inform people of the need to enact planning processes with the members of the community where they can determine how they want to manage potential forces of gentrification and where they can choose to enact such measures as anti-displacement policies and practices.

The Data of the Smart Mobility Calculator

The data and sources that show up on the calculator's dashboard on the right side of the screen are shown in Table 3.

As shown in Table 3, the SM calculator provides two types of data: the first are urban quality outcome metrics that gauge the sustainability, livability, and equity performance of an area. For these measures lower values are better, such as lower VMT, lower carbon emissions, housing costs, etc. Second are urban form livability opportunity measures. These are measures of the built environment that provide people the ability to access livability opportunities—such as ability to access jobs via walking and transit.

Table 3. The Metrics of the Smart Mobility Calculator

Metric	Data Source(s)
Sustainability, Livability, Equity Performance Lower Values are Better	
Vehicle Miles Traveled per Capita	Caltrans' California State Travel Demand Model (CSTDM) 2016 using 2012 California Household Travel Survey
Vehicle Miles Traveled per Household	From HUD's 2012 Housing Affordability Index Data Set (HAI) - hh_type1_vmt- Vehicle Miles Traveled per Household (the authors are working to get updated VMT per capita data from Caltrans)
Housing Affordability	HUD's 2012 Housing Affordability Index Data Set (HAI) (the authors use this measure as it is aggregated to Census Block Group level) hh_type1_: housing cost as a percent of income for the regional typical household, defined as Avg HH size for region, median income for region, average number of commuters per HH for region
Transportation Affordability	From HUD's 2012 Housing Affordability Index Data - hh_type1_t
Pedestrian Collisions per 100,000 Pedestrians	Transportation Injury Mapping System (TIMS) 2010 Pedestrian collisions per 100,000 pedestrians
WalkScore	Frontseat
Cardiovascular Disease	Centers for Disease Control: 500 Cities Data Cardiova_1
Obesity	Centers for Disease Control: 500 Cities Data OBESITY_Cr
Urban Form/Livability Opportunities Higher Values are Better	
Transit Jobs Accessibility	EPA's Smart Locations Data Set (SLD) 2013 D5br: Jobs within 45-minute transit commute, distance decay (walk network travel time) weighted
Population Density (population/acre)	SLD D1b: Gross population density (people/acre) on unprotected land
Jobs Density (employees/acre)	SLD D1c: Gross employment density employees (jobs)/acre on unprotected land, 2013
Pedestrian Environment (intersection density)	SLD D3bmm4: Intersection density in terms of multimodal intersections having four or more legs per square mile

VMT and a Place Typology

Why is VMT per capita the first layer that shows up when you open the SM Calculator? VMT per capita is used as this is one of the most important measures for key issues we are trying to address, such as housing, climate action planning, and the new environmental regulations replacing level of service (LOS) with VMT (per SB 743). In addition to VMT, the SM Calculator also provides a place typology based on Caltrans' own Smart Mobility Framework, also using the Location Efficient Neighborhood Design (LEND) Index, as shown below.

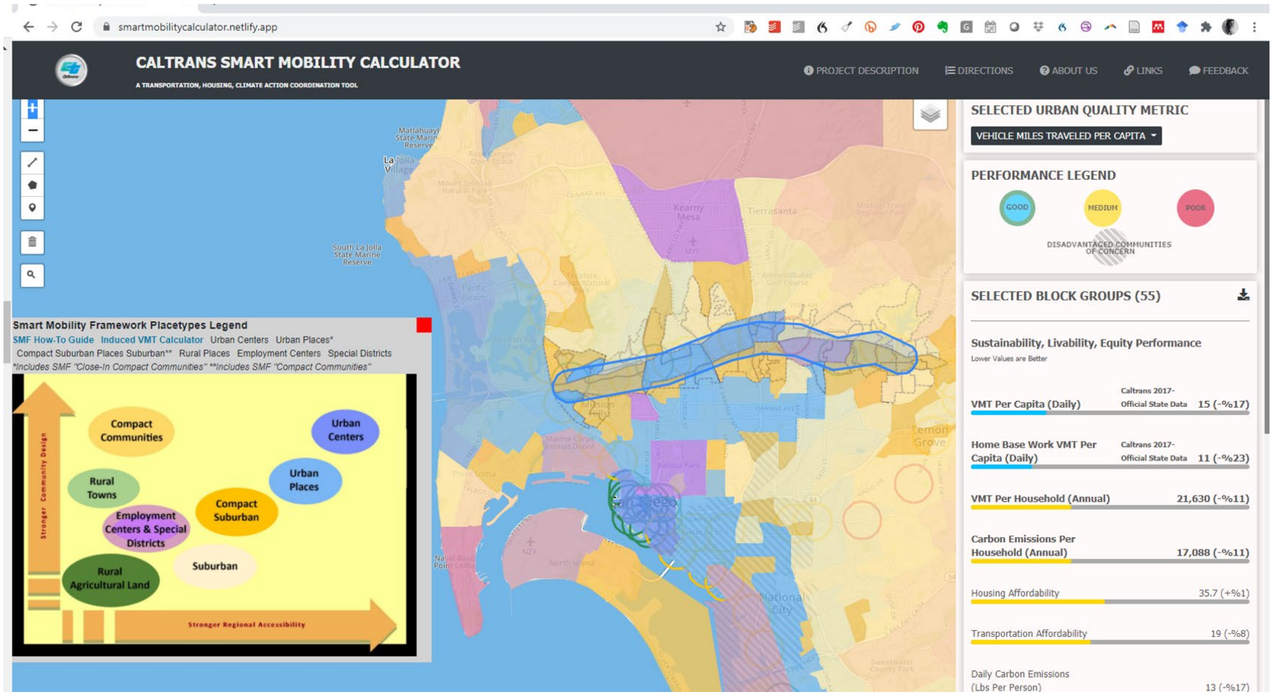

Figure 6. The Location Efficient Neighborhood Design (LEND) Smart Mobility Framework Place Typology in the Smart Mobility Calculator

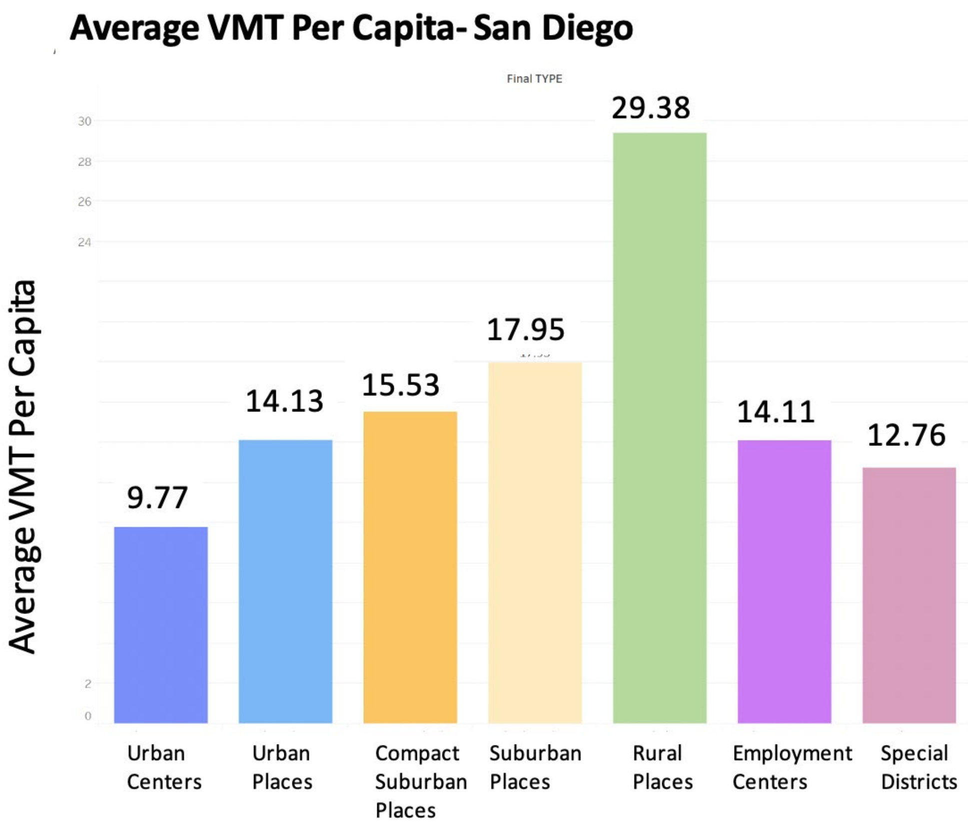

Figure 7. Average VMT per Capita Using the Location Efficient Neighborhood Design (LEND) Index and Caltrans' SMF Place Typology in San Diego

Using VMT: The Transportation Land Use Connection

The connection between lower vehicle miles traveled (VMT) and urban (versus suburban) places, illustrated above, shows how achieving a better balance between housing and jobs can lead to more sustainable outcomes. As shown in Figure 7 above, by doing such things as encouraging infill development and curbing urban sprawl, a coordinated transportation and land use planning approach can improve a regional transportation plan by lowering overall trip distances and automobile travel in support of transit, walking, and bicycling. Such VMT reductions can be realized through both regionally minded land use planning and pricing policies, which should be supported at all levels of government.

THE USES OF THE SMART MOBILITY CALCULATOR

In brief, the Smart Mobility Calculator can be used in the following ways:

- Caltrans' New Corridor Planning Process: The SM Calculator can help with all aspects of Caltrans Corridor Planning Process, especially in the initial stages (see next section).

- CEQA project development review analysis under SB 743: The SM Calculator can help with project development review analysis under the new regulations of SB 743 which allows for environmental streamlining of significant developments in areas that are 15% below regional averages for VMT.

- *Climate action planning:* The SM Calculator shows how many pounds of carbon per household will be generated from travel in different locations in the region, which can help with dialogues around climate action planning.

- *New housing initiatives:* This tool can help ensure new housing initiatives are equitable: first, it shows the areas that are in close proximity to transit, while also showing the location of disadvantaged communities, per SB 535, which is key to then being able to inform people to enact anti-displacement policies and practices.

- Better transportation and land use coordination between regional transportation planning agencies and local land use authorities, by providing key transportation and land use information at both regional and local scales.

- Helps inform NIMBY conversations by giving people access to key data, such as VMT and pounds of carbon per household in order for all parties to better understand why development should occur in transit/bike/walk accessible areas; by giving people a regional perspective and helping them see how everything is connected and needs to be coordinated through both land use and transportation, everyone can get on the same page and have a more constructive dialogue.

- Performance evaluation of future scenarios related to Autonomous Vehicles (AVs) and Mobility as a Service (MaaS).

- The SM Calculator also provides an atlas of all train stations in California, rating them according to their performance as described in the smart growth & transportation/ land use coordination (TLC) performance typology outlined in the paper “Are All Stations Equal and Equitable?” (Appleyard et al. 2019).

V. ILLUSTRATIVE EXAMPLES OF THE SMART MOBILITY CALCULATOR IN ACTION

CALTRANS' NEW CORRIDOR PLANNING PROCESS

Both the Livability and Smart Mobility Calculators can be used for Caltrans' new corridor planning process. They can be used in all phases, especially in the beginning. This section provides an illustrative example of how to use both the SM Calculator and the Livability Calculator toward Caltrans' Corridor Planning Process. For instance, the Smart Mobility Calculator provides the SMF place typology which can provide important insight into the context of a corridor for the baseline performance assessment (see Figure 8).

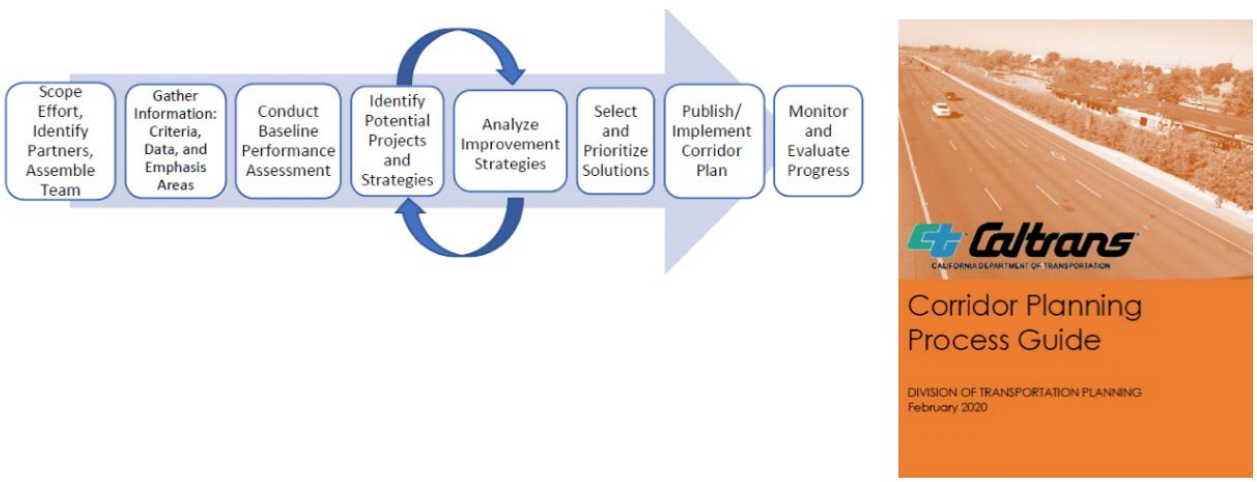

Figure 8. The Caltrans Corridor Planning Process

The Smart Mobility Calculator can also be used to assess the SMF place types for a corridor, which is especially important in the initial phases of the corridor planning process.

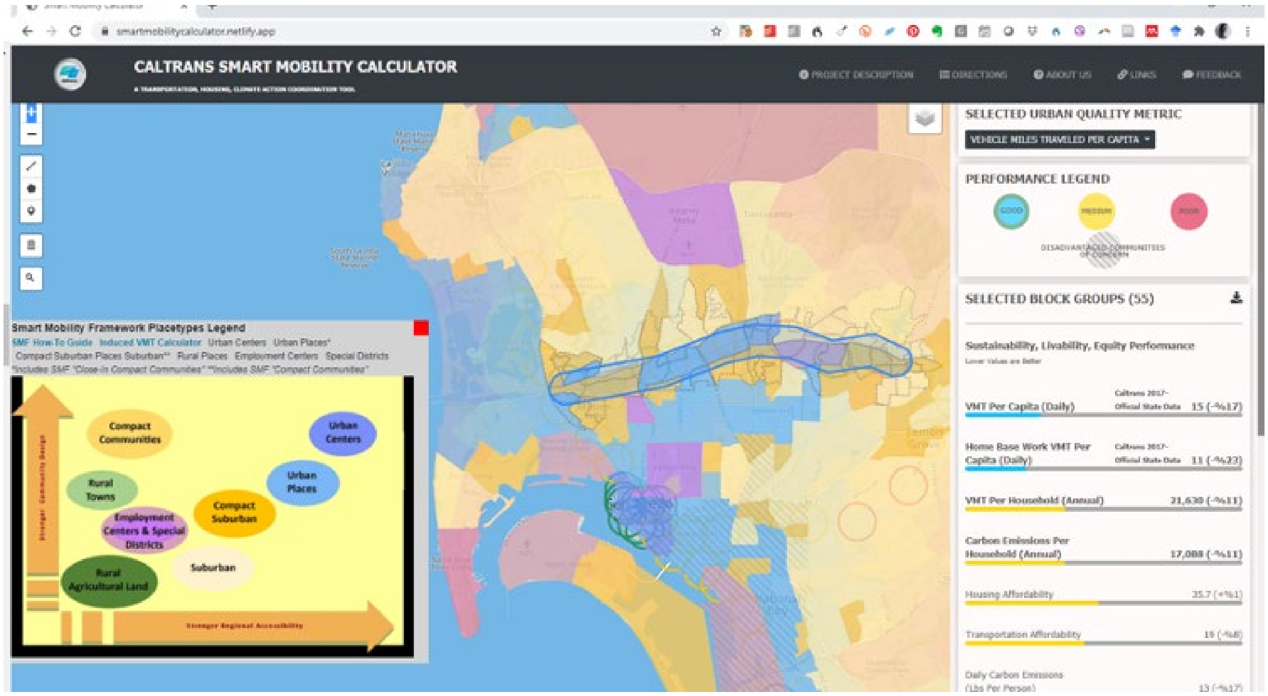

Figure 9. The SMF Place Types Can Also be Displayed in the Smart Mobility Calculator and Used in the Caltrans Corridor Planning Process

The calculators can also be used to develop the required Sustainability Profile which should focus on "reporting corridor performance related to policies that practice environmental stewardship and the fostering of livable, healthy, and equitable communities" (Caltrans Corridor Planning Process 2020). Examples of such measures provided in both Calculators include:

- Criteria pollutants and GHG emission estimates
- VMT per capita in areas served by the corridor
- Measures of multimodal accessibility and connectivity for households and employers

Below is a step-by-step illustrative guide to using the calculators for the corridor planning process, using the I-8 corridor as a case study.

1. Select your corridor of interest in the Smart Mobility Calculator.
2. Download the data from the Smart Mobility Calculator.
3. Select the FIPS codes and input into the Livability Calculator's Input Sheet.

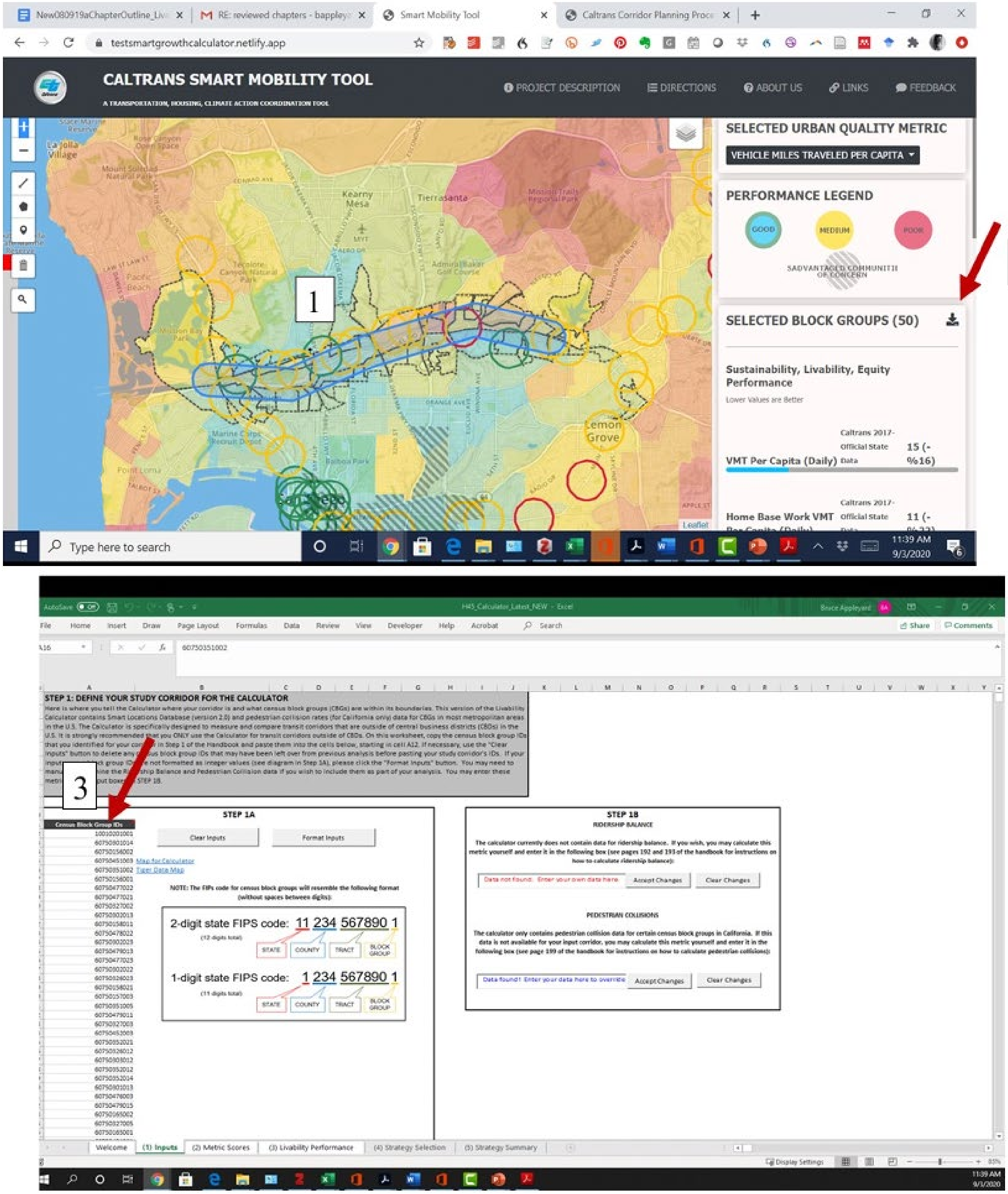

Figure 10. Selecting a Corridor in the Smart Mobility Calculator, then Inputting the FIPS Code Data into the Livability Calculator's Input Sheet

4. View your corridor's livability performance on the Livability Performance Sheet of the Livability Calculator.

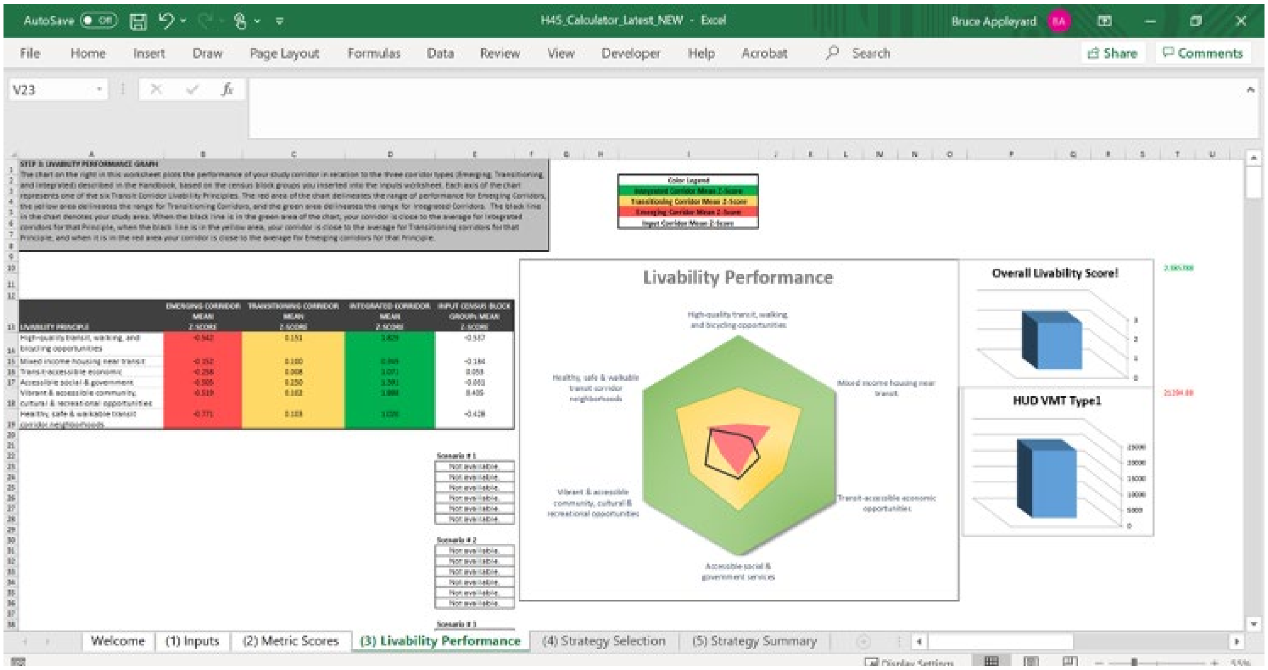

Figure 11. Corridor Performance Displayed in the Livability Performance Sheet on the Livability Calculator

5. Select policies from the Strategy Selection and Strategy Summary Sheet. (Make sure you have a copy of the Handbook for Building Livable Transit Corridors in the same folder as the Livability Calculator).

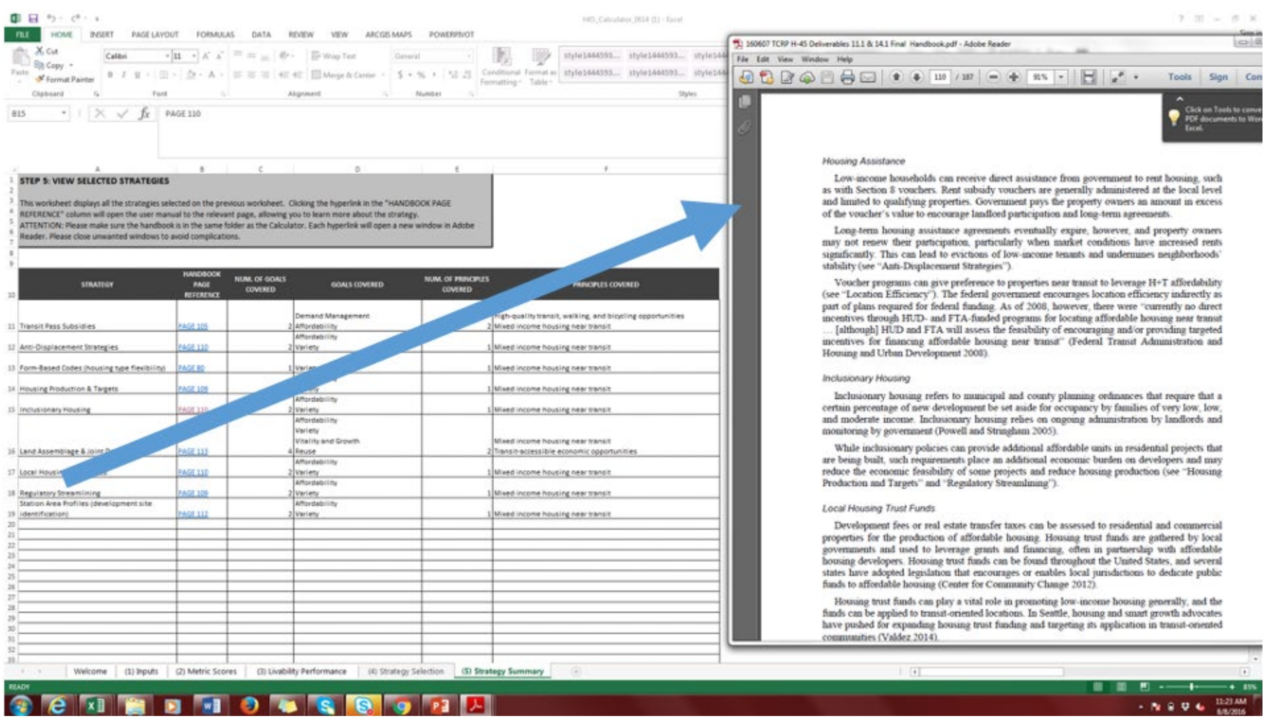

Figure 12. Displaying Policy Options in the Handbook for Building Livable Transit Corridors via the Livability Calculator's Strategy Summary Sheet

VI. NEW ENVIRONMENTAL REGULATIONS FOR PROJECT DEVELOPMENT REVIEW: USING THE SMART MOBILITY CALCULATOR FOR VMT INSTEAD OF LEVEL OF SERVICE — AN ILLUSTRATIVE EXAMPLE

Senate Bill 743—which allows for environmental streamlining of significant developments in areas that are 15% below regional averages for Vehicle Miles Travelled (VMT) —could be a significant game changer in California's ability to achieve a more sustainable, livable, and equitable future.

Why should VMT be below 15% of regional averages? According to the California Office of Planning Research, 15% below is chosen as the benchmark for the following reasons:

- Caltrans Strategic Plan: Reduce VMT/cap 15% by 2020
- SB 375 targets ≈ 15% collectively statewide
- AB 32 scoping plan recommends local governments set GHG
- Reduction targets at 15% below existing by 2020
- Research shows 15% VMT mitigation is generally achievable (See CAPCOA's Quantifying Greenhouse Gas Mitigation Measures)

HOW USING VMT INSTEAD OF LEVEL OF SERVICE HELPS TRANSFORM OUR AUTO-MOBILITY PARADIGM

The pictures in Figure 13 illustrate a critical problem with using level of service (LOS) for evaluating new developments, especially if the goal is to achieve more sustainable, livable, and equitable outcomes. The top image shows an open road that has no congestion. Under the old level of service paradigm dictated by CEQA , this would receive the highest grade, A, while the congested road at the bottom would receive a lower grade, possibly an F. The problem is that this type of street is more likely located in a suburban or ex-urban area with a low density—and perhaps more importantly, lower levels of regional centrality and access to jobs. Using the SM Calculator, it can be seen that such an area could have relatively high levels of annual vehicle miles traveled per household—somewhere in the range of 25–28,000 VMT per household per year. On the other hand, a more regionally central area, as shown in the bottom photo could be more congested (receiving an LOS grade of F) but be located in an area that generates much lower VMT per household, somewhere in the range of 15,000 to 18,000 VMT per year.

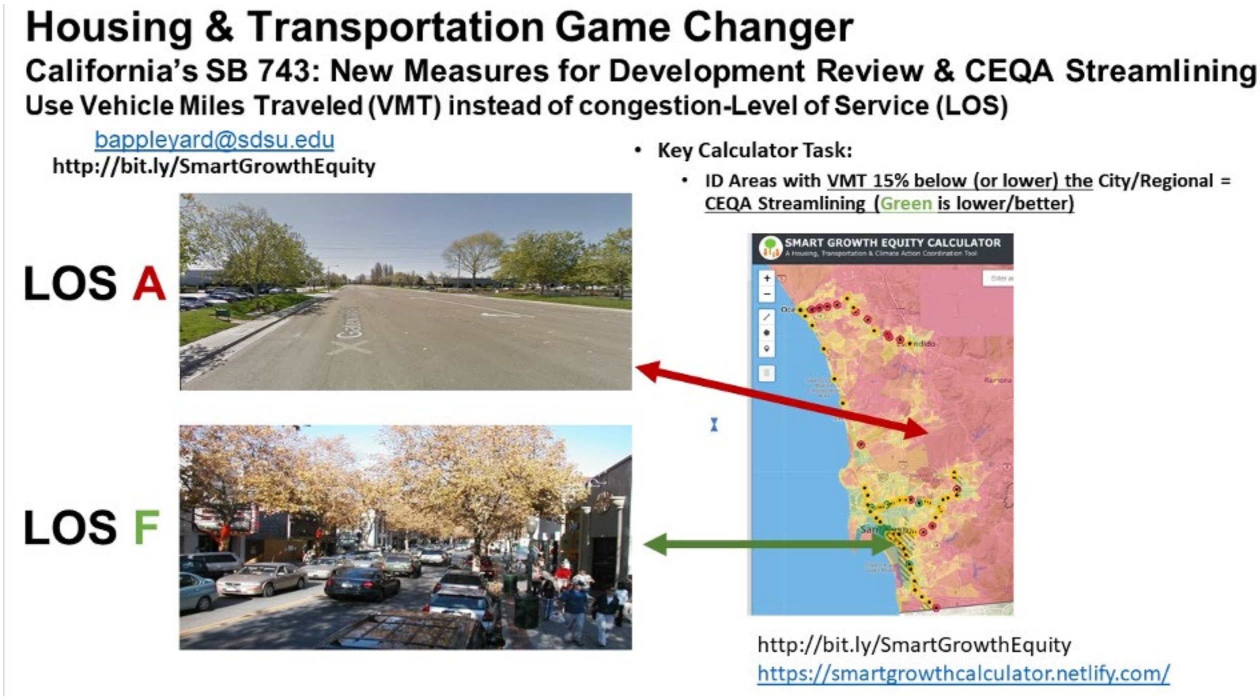

Figure 13. SB 743 Visualization and Examples in Smart Mobility Calculator

HOW THE SMART MOBILITY CALCULATOR CAN HELP WITH VMT ANALYSIS FOR THE CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA)

The SMC can help in California Environmental Quality Act (CEQA) analysis by enabling measurement of the VMT per capita for one's area of interest in relation to agreed-upon regional average. In the example in Figure 14 below, the selected area—which is the El Cajon Boulevard corridor just to the south and west of San Diego State University—is compared with the average VMT per capita for the entire county of San Diego.

Remember, to select an area use the corner selection tool on the left-hand side of the screen. (If selecting another area be sure to deselect the initial area by selecting the trash can icon at the bottom of the toolbox to clear the selection.)

The SM Calculator then calculates a collective average for the urban quality metrics across the selected area and compares it to the regional average. In the example below, the area of interest is cumulatively at about 27% below the regional average, meaning it qualifies for environmental review streamlining under CEQA as per SB 743.

While more specific analysis is likely needed, this geographical area shows promise for achieving the target of 27% below the regional average. Under the new California Environmental Quality Act guidelines, per the new SB 743 regulations, this means that significant projects in this area may qualify for development review streamlining. Conversely, these averages can reveal certain areas that are well above the regional average for VMT and should no longer receive the benefits that these areas used to receive under the old level of service (LOS) paradigm (which favored areas that were low density, regionally inaccessible, and consequently more auto-dependent).

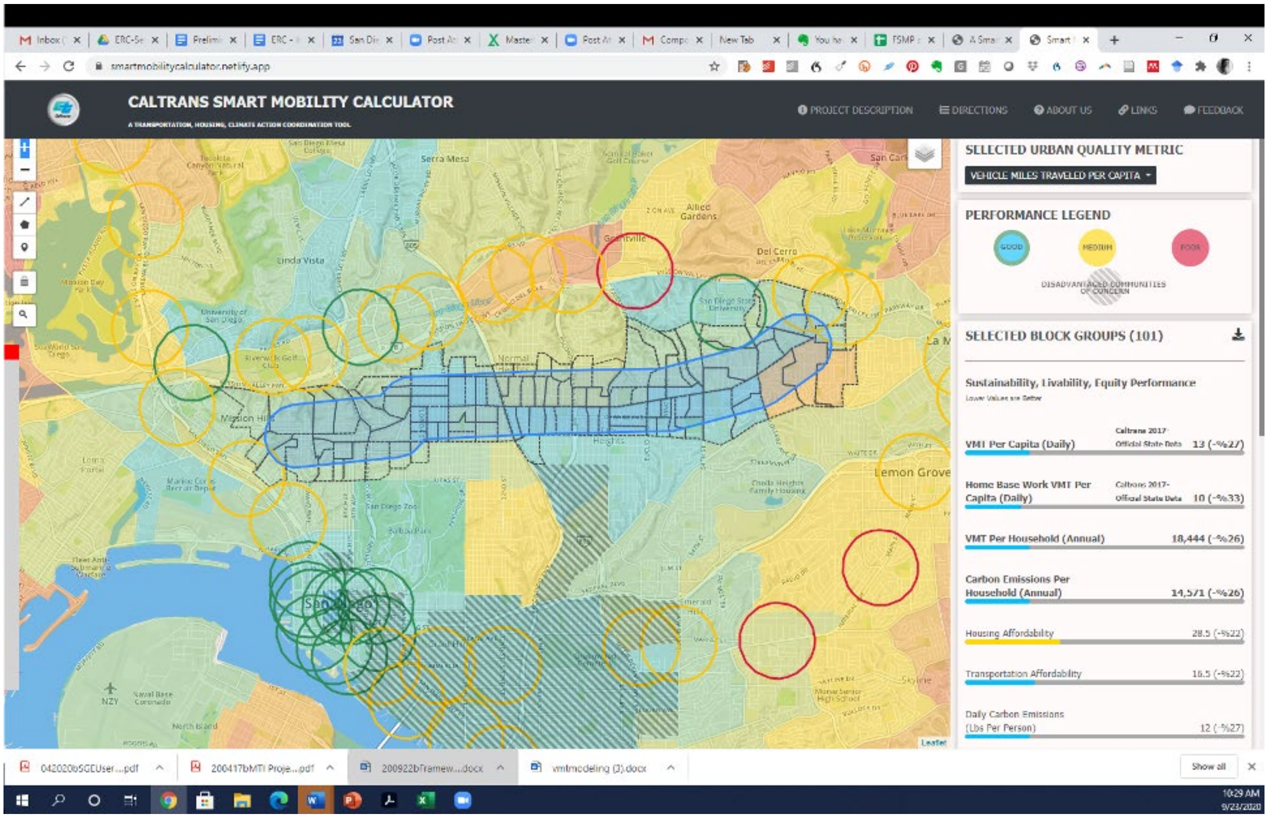

Figure 14. Smart Mobility Calculator Used to Determine SB 743 Compliance

TOD ATLAS: THE EQUITY OF URBAN QUALITY AROUND TRAIN STATIONS

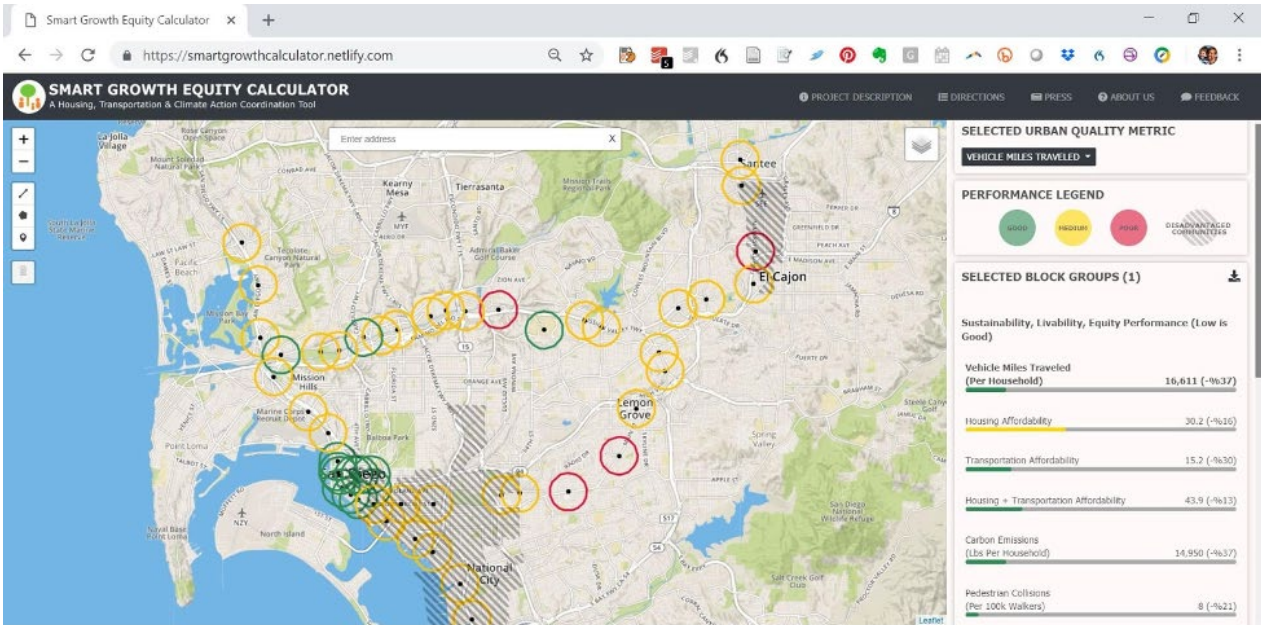

Figure 15. Light Rail Station Performance and 1/2-mile Overlay in the Smart Growth Calculator

Station color key: Red = Emerging; Yellow = Transitioning; Green = Coordinating/Integrating

In the Smart Mobility Calculator, all the light rail stations are color coded according to their performance as described in the smart growth and transportation/land use coordination (TLC) performance typology outlined in the paper "Are All Stations Equal and Equitable?" (Appleyard et al. 2019). Red = Emerging; Yellow = Transitioning; Green = Coordinating/Integrating. The indicators on the right show the performance of a sample coordinating station, which has lower regional averages for household vehicle miles traveled, carbon emissions, and transportation expenditures, but lacking in terms of being affordable because of paradoxically higher housing costs. The hatched areas on the map locate California-designated disadvantaged communities deserving protection from forces of displacement via targeted policies. For more information, see https://smartmobilitycalculator.netlify.app/ (Appleyard et al., 2018).

VII. CALTRANS' SMART MOBILITY FRAMEWORK IMPLEMENTATION PROJECT CASE STUDY

Understanding the performance of urban places in relation to levels of transportation and land use coordination is key to determining the best policy pathways forward for transportation and land use agencies to realize sustainability, livability, and equity outcomes.

This section starts with a discussion of Caltrans' own Smart Mobility Framework (SMF) Implementation project conducted between 2012 and 2014, highlighting the work by Caltrans and LA MTA to develop place typologies to better understand the performance of urban places in terms of levels of transportation and land use coordination. It then discusses the development of a new place typology based on Caltrans' own SMF place typology. Through reaching an understanding of this performance, we can determine the best policy pathways going forward to realize sustainability, livability, and equity. An overview of the Smart Mobility Framework here will help provide the necessary context to understand the underlying mechanisms in the Smart Mobility Calculator.

For more on this, and a detailed discussion of the results of a practitioner survey, see the Appendix.

IMPLEMENTATION FRAMEWORKS TO COORDINATE TRANSPORTATION AND LAND USE IN DECISION-MAKING PROCESSES

Building on the definitions and frameworks discussed above, this report can help agencies such as Caltrans achieve transportation and land use coordination by informing decisions on both sides of the transportation and land use equation.

Place Types and Measurement Constructs

Between 2012 and 2014, Caltrans embarked on two Smart Mobility Framework Implementation projects: one in Southern California and one in Northern California. This section reviews and reflects on some of the main components of SMF (Smart Mobility Framework) and its implementation in Southern California. As shown in Figures 16 and 17, there appears to be a clear association between (a) the SMF place types framework and (b) LA MTA's Accessibility Clusters, as part of LA MTA's Metro Countywide Sustainability Planning Policy.

Figures 16 and 17 show key components of both the SMF and Metro place type frameworks that can be used to identify areas with the greatest potential to evolve into more sustainable places. Looking at Figures 16 and 17 below, it can be seen that they both use a similar 2×2 matrix with some measure of regional accessibility along the horizontal axis: SMF uses Regional Accessibility, while Metro has developed a similar measure, Job Centrality. Where they slightly differ is that they both have local-level measures, but in the case of Metro, Population Density is used, while the SMF uses Strong Community Design.

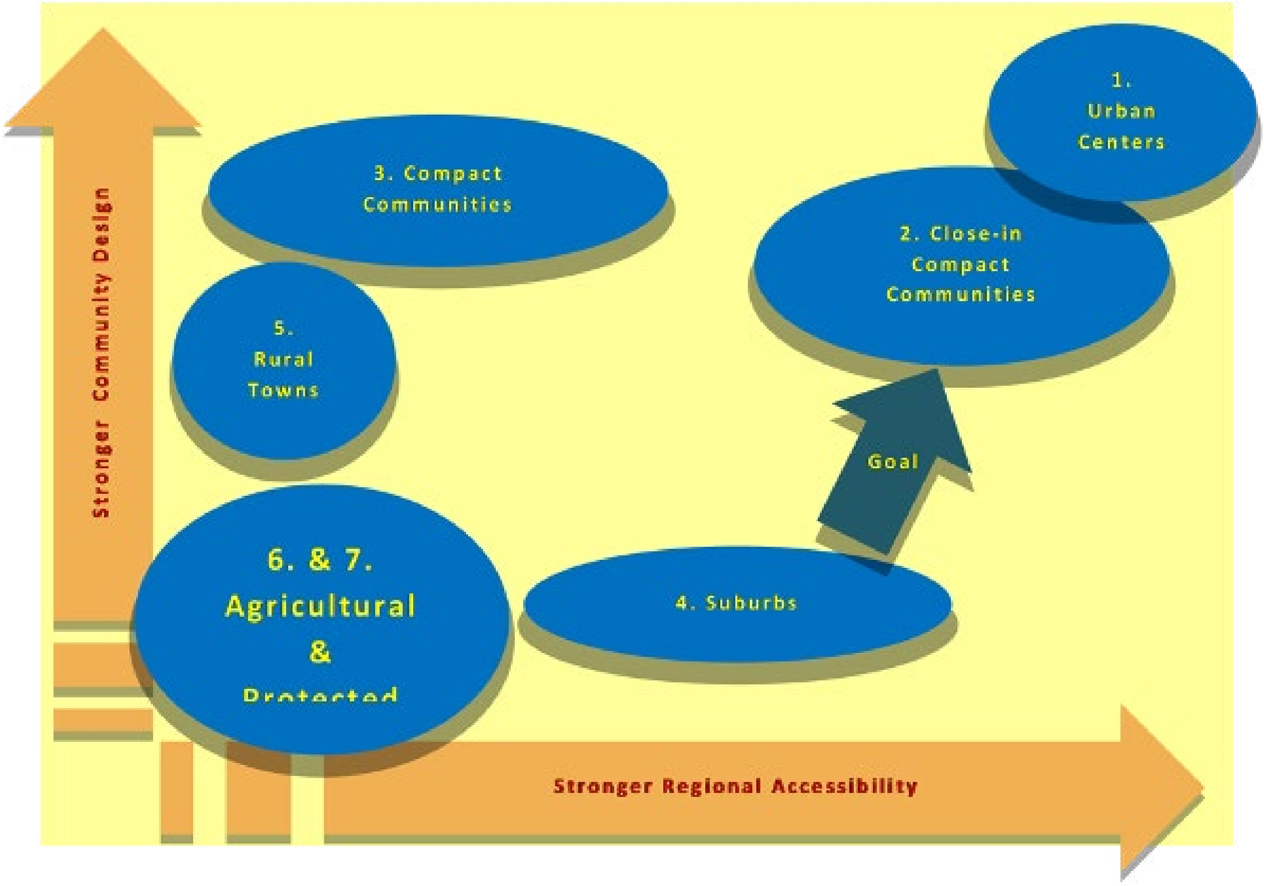

Figure 16. Smart Mobility Framework

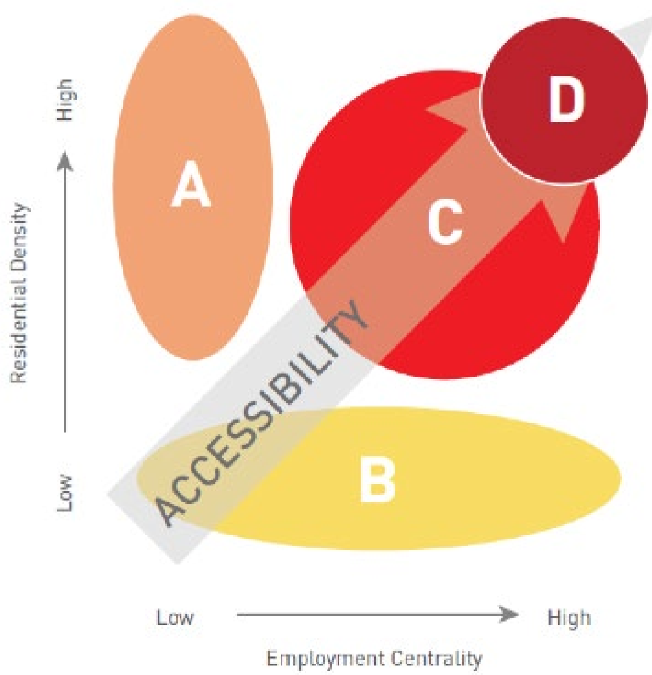

Figure 17. Metro Place-Type Framework

In both cases, there is an attempt to present what is happening at the local level to determine which areas can facilitate Local Accessibility (which should include non-motorized Transportation facilities) to be cross-referenced with Regional Accessibility. And while Population Density is a coarse proxy, Community Design can be somewhat elusive, but not impossible to measure—the authors would recommend a combination of walkability (intersection density and network connectivity) and local access to jobs and services, which can be found in something like the network-based measure WalkScore.

Building on frameworks and measures discussed herein, the research team can help agencies such as Caltrans achieve transportation and land use coordination by informing decisions on both sides of the equation. For illustration purposes, it is possible to build from Metro's Accessibility Clusters concept as part of work on the Smart Mobility Framework Implementation project. Figures 18 and 19 depict key accessibility clusters of the Metro place type framework, alongside how they were identified in the Hawthorne Study Area as part of the Smart Mobility Framework Implementation project in Southern California.

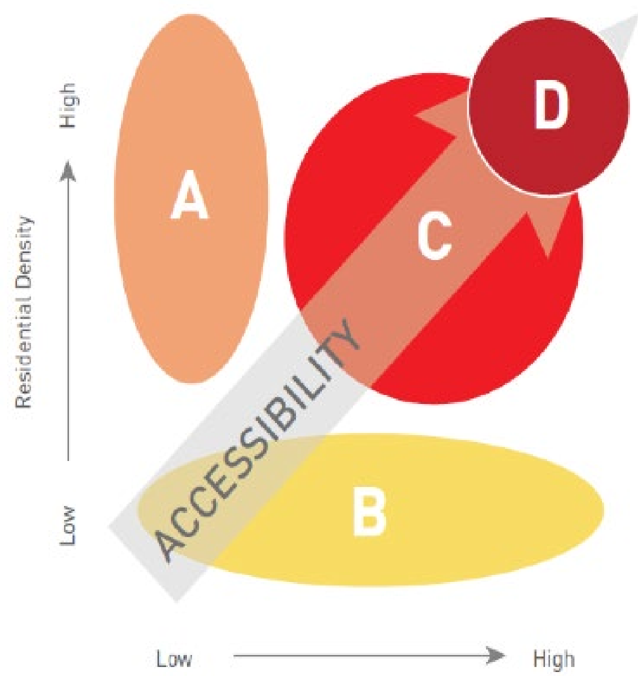

Figure 18. Metro Place-Type Framework

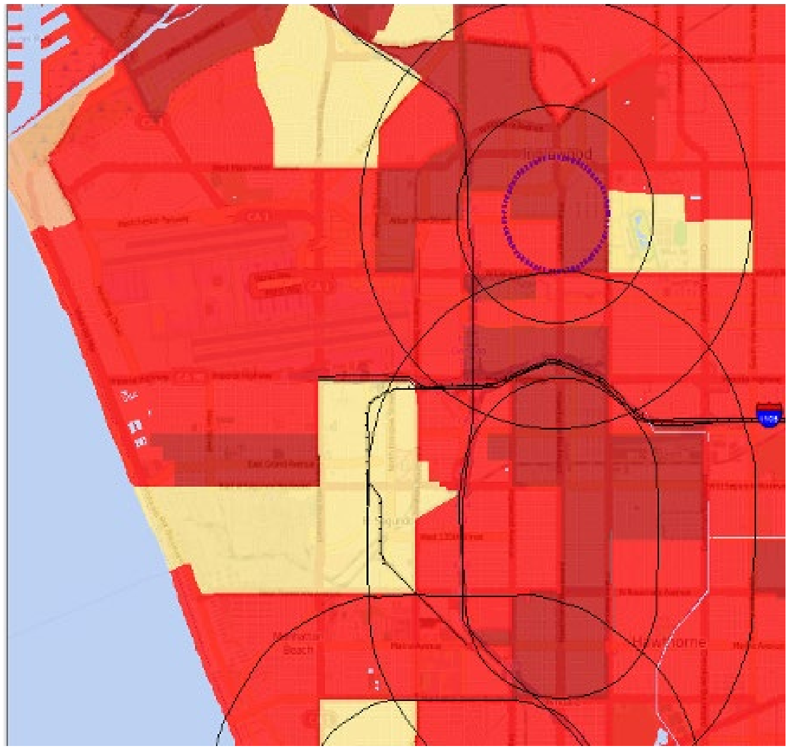

Figure 19. Accessibility Clusters of the Metro Place-Type Framework in the Hawthorne Study Area

Creating and Mapping a Place Typology Based on Location Efficiency and Neighborhood Design (LEND)

If both the LA MTA and Caltrans SMF frameworks are to be distilled into two key components, they could be Location Efficiency (a regional scale measure) and Neighborhood Design (a local scale measure). Therefore, building on experiences working on the SMF Implementation project, the principal researcher developed a Location Efficient Neighborhood Design (LEND) place type index. The maps and legend are shown in Figure 20.

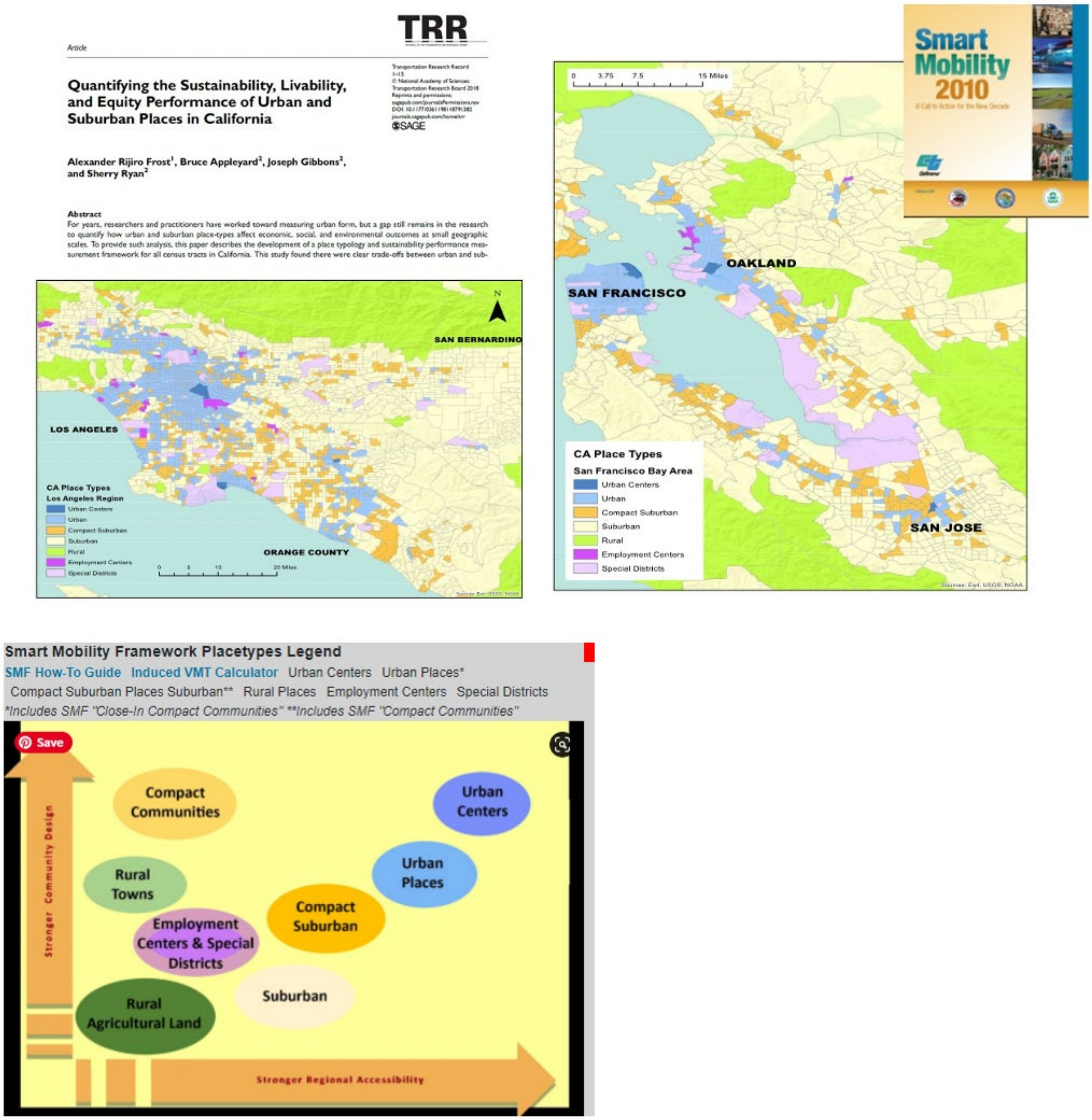

Figure 20. Maps and Legend Based on Location Efficient Neighborhood Design (LEND) for Smart Mobility Framework Place Typology

These GIS databases have been included in the Smart Mobility Calculator and provided to Caltrans with the intention of Caltrans using them for Smart Mobility Framework implementation and corridor planning going forward.

Figure 20 shows key components of the Location Efficient/Neighborhood Design Framework that can be used to identify areas with the greatest potential to evolve into more sustainable places. Looking at the graphic above, a similar matrix to both LA MTA's CSPP and Caltrans SMF, with a dimension for regional accessibility (Location Efficiency) along the horizontal axis, and Neighborhood Design along the vertical axis. As SMF suggests using a measure of Regional Accessibility, while Metro recommends using a similar measure, Job Centrality, the SM Calculator (https://smartmobilitycalculator.netlify.app/), provides the measure of Jobs Accessible within a 45-minute transit trip. The authors recognize that also providing a measure of Jobs Accessible within a 45-minute auto trip would be useful in conveying the VMT reduction benefits of both regional access and centrality (Cervero & Duncan 2003).

Using the SM Calculator to Implement the SMF: Toward the Coordination of Transportation and Land Use

This section introduces a general approach to apply the Smart Mobility Calculator, specifically its use of VMT per capita and household to understand places in a region, with the aim being to guide Caltrans' policies to improve transportation and land use balance and coordination, both within and outside the organization. It also provides guidance for how the Smart Mobility and Livability Calculators can be used in Caltrans' new corridor planning processes.

Building on frameworks and measures discussed above with LA MTA's CSPP and Caltrans' SMF, it is possible to use the Smart Mobility Calculator (https://smartmobilitycalculator.netlify.app/) developed by the research team, as well as the data the authors are working with related to the Location Efficient Neighborhood Design (LEND) Index to help agencies such as Caltrans, MPOs, and local land use authorities achieve better transportation and land use coordination and, by extension, achieve a host of sustainability, livability, and equity outcomes.

Brief Overview of the Smart Mobility Calculator

VMT per capita, by census block group, is the first layer that shows up when you open the SM Calculator. VMT per capita is used as it is one of the most important measures for key issues we are dealing with, such as housing, climate action planning, and the new environmental regulations replacing LOS with VMT as per SB 743.

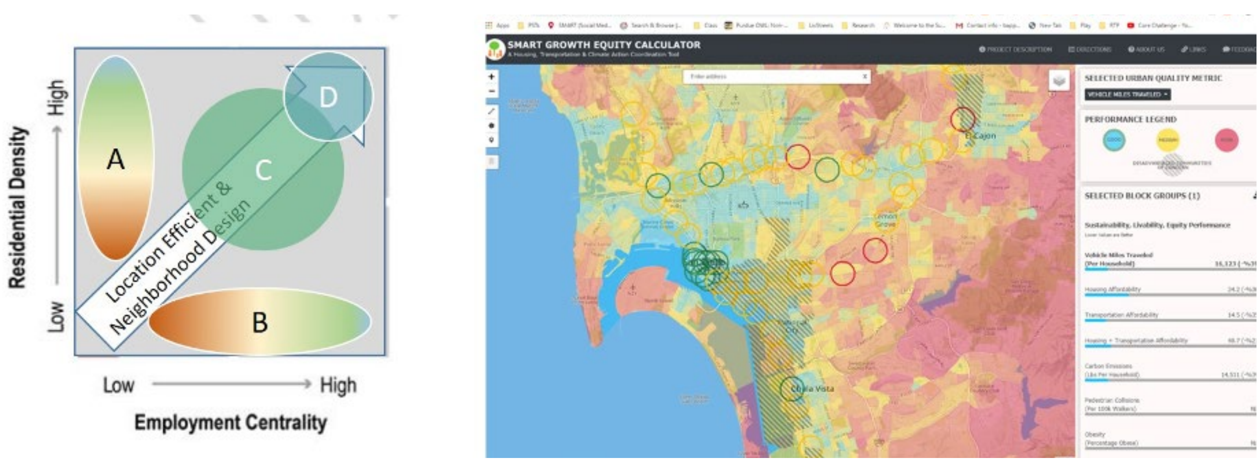

Figure 21. Location Efficient/Neighborhood Design Framework and Smart Growth Calculator

Figure 21 shows key components of the Location Efficient/Neighborhood Design (LEND) framework that can be used to identify areas with the greatest potential to evolve into more sustainable places. Looking at the graphic above, it has a similar matrix to both LA MTA's CSPP and Caltrans SMF with a dimension for regional accessibility (Location Efficiency) along the horizontal axis, with Neighborhood Design along the vertical axis. The map in Figure 21 shows a representation of VMT-based place types, as indicated in the SM Calculator, with hot reddish colors showing areas of high VMT (20–28,000 VMT per capita) and cool, blue/green colors showing places with low VMT per capita (15–18,000 VMT per capita). As discussed below, both the graph and the map have the ability to guide policy, specifically related to the coordination of transportation and land use.

The Importance of Transportation and Land Use Coordination as a Function of Accessibility between Homes and Jobs, Lowering Vehicle Miles Travelled (VMT)

Measures of job and housing accessibility embody the two key characteristics of the transportation/land use equation with the following two components: (a) *proximit*y (how close activities are, mostly determined by land use planning); and (b) *mobility* (how quickly and easily one can use the transportation system to arrive at a chosen destination). The greater the access between housing and jobs—which is largely a function of transportation/land use coordination—the lower the amount of vehicle travel (Boarnet and Wang, 2018; Cervero and Duncan, 2006)"source":"escholarship.org","abstract":"To achieve the greenhouse gas emission reduction goals established by California Assembly Bill 32 and California Senate Bill 375 will require policy approaches that address the link between land use and vehicle travel. The extensive literature on land use and travel behavior has documented the association between employment access and vehicle miles traveled (VMT. Therefore, in many ways, VMT is a good measure capturing the underlying coordination and balance, or lack thereof, between transportation and land use coordination. More guidance is provided below.

Location Efficiency

For Location Efficiency, Caltrans' SMF suggests using a measure of Regional Accessibility, while Metro's CSPP recommends using a similar measure of Job Centrality. The SM Calculator provides the measure of Jobs Accessible within a 45-minute Transit Trip. The authors recognize that additionally providing a measure of Jobs Accessible within a 45-minute Auto Trip would be useful in conveying the VMT Reduction benefits of both access and centrality (Boarnet and Wang, 2018; Cervero and Duncan, 2006)"source":"escholarship.org","abstract":"To achieve the greenhouse gas emission reduction goals established by California Assembly Bill 32 and California Senate Bill 375 will require policy approaches that address the link between land use and vehicle travel. The extensive literature on land use and travel behavior has documented the association between employment access and vehicle miles traveled (VMT).

Neighborhood Design

Along the vertical axis is the dimension of Neighborhood Design, which is meant to capture what is happening at the local level—ostensibly to determine which areas can facilitate local accessibility through NMT modes (walking, bicycling, transit, scootering, etc.).

For local-level measures, LA MTA's CSPP uses Population Density, while the SMC uses a more comprehensive "Community Design." In both cases, the goal is to present what is happening at the local level to determine which areas can facilitate walk- and bike-ability and local accessibility to be cross-referenced with Regional Accessibility. The authors recommend using a combination of walkability (intersection density and network connectivity) and local access to jobs and services, which can be found using network-based Walkscore—which are all provided in the dashboard readout of the Smart Mobility Calculator.

Informing Transportation Decisions

On the transportation side, measures of Location Efficiency (centrality and regional access, mostly to jobs) as well as Neighborhood Design (high intersection density for route directness & walkability, WalkScore for local access, and/or population density) help identify the important locations for transportation investments to meet local and regional connectivity needs. In other words, these measures help identify where we should be focusing investments for human-scale transport *connectivity* (walking, bicycling, transit).

Informing Land Use Decisions

This information is also useful in informing land use decisions. Location Efficiency (Centrality and Regional Access—mostly to jobs) reveals the areas accessible to jobs. High job access locations should be where the highest population densities are located (with better walking and bicycle facilities). Therefore, a highly Location Efficient (centrally located, regionally accessible) area with a low population density would indicate where more population (dwelling units) should be constructed. Conversely, high population density areas (Neighborhood Design) with low location efficiency are areas that need more jobs and other important activities.

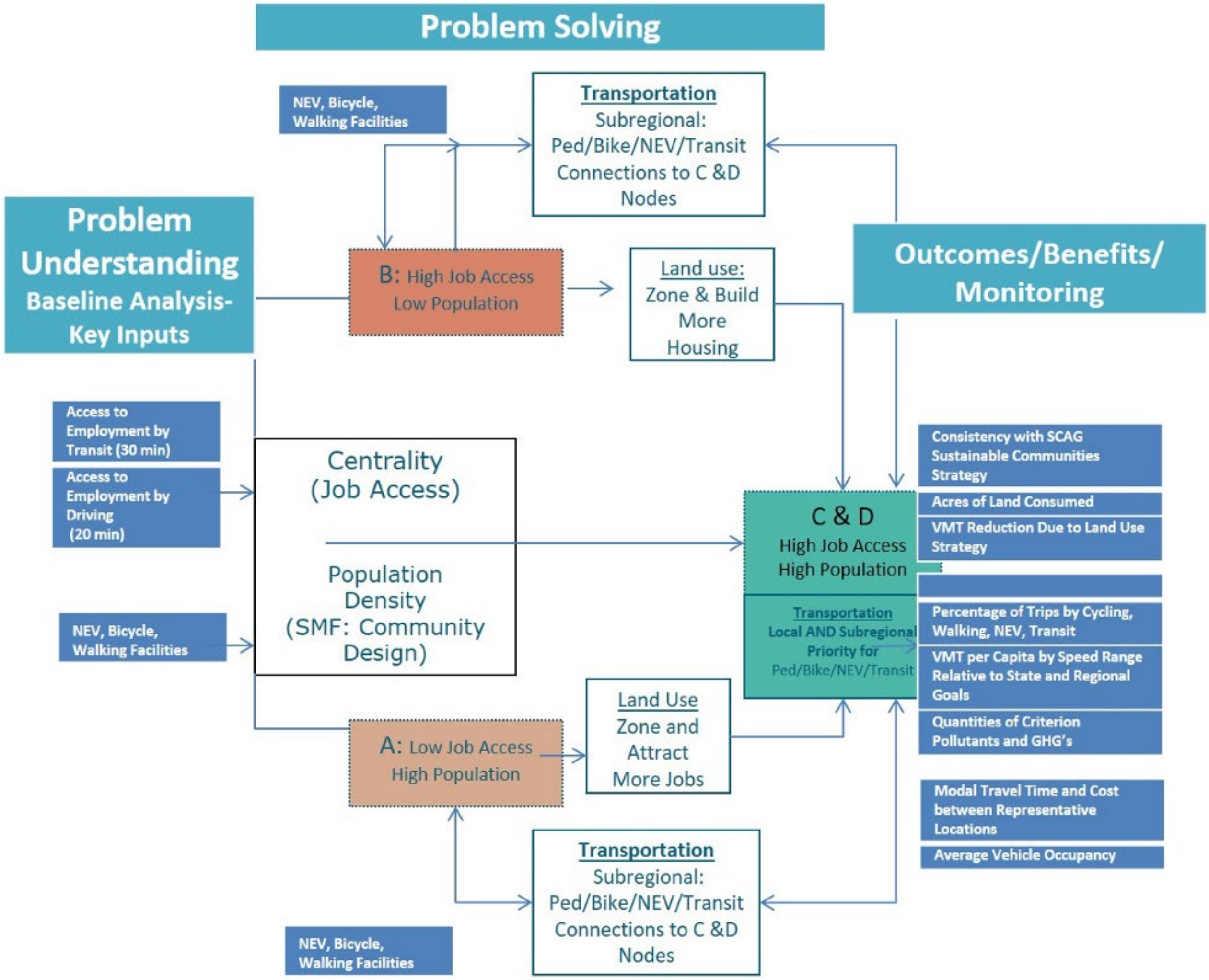

Figure 22. Basic Framework for Transportation and Land Use Decisions Using the LEND Clusters Concept

Building on the preceding discussion, Figure 22 provides a basic policy decision tree for transportation and land use actions using the LEND Framework with the SM Calculator. (This could also be used for both Metro's CSPP and Caltrans' Smart Mobility Framework—just the color coding needs to change.)

Cluster/Nodes A

In clusters with low levels of Location Efficiency (low regional access to jobs) with a moderate to high population density requires zoning to attract more jobs. Occupationally matching the jobs and housing balance is the best way to lower VMT (Cervero, Rood, and Appleyard, 1999; Cervero and Duncan, 2006). On the transportation side, look to make some regional connections to the C&D nodes.

Cluster/Nodes B

On the other hand, high Location Efficiency (Centrality or Regional Access to Jobs) but low Neighborhood Design (low population density), as shown in Accessibility Cluster B, requires actions such as zoning to increase population and housing density. On the transportation side, seek to form some sub-regional connections between the nodes, especially connecting to the C&D nodes, using sustainable modes, such as transit, bicycling, walking, or person-sized vehicles PSVs (scooters).

Cluster/Nodes C&D

For the C&D nodes that balance Location Efficiency to jobs and high Neighborhood Design (high population density and walkability), prioritize transportation projects that increase both internal (local) and external (regional) connectivity, focusing on sustainable modes, such as transit, bicycling, walking, and person-sized vehicles PSVs (scooters).

The Big Picture

Before the section wraps up, Figure 23 provides a conceptual meta-view of the ecosystem of performance measures, their production, and finally their application in terms of policies and actions. Oftentimes the agency which gathers and produces the measure, such as the MPO, is not able to put it into action for a more sustainable future. Therefore, there is a very important process of knowledge transfer that should occur. A measure dealing with the number of jobs accessible by transit relies on multiple agents to achieve a sustainable outcome: transit service providers, local traffic engineers, and perhaps more importantly, local land use planners.

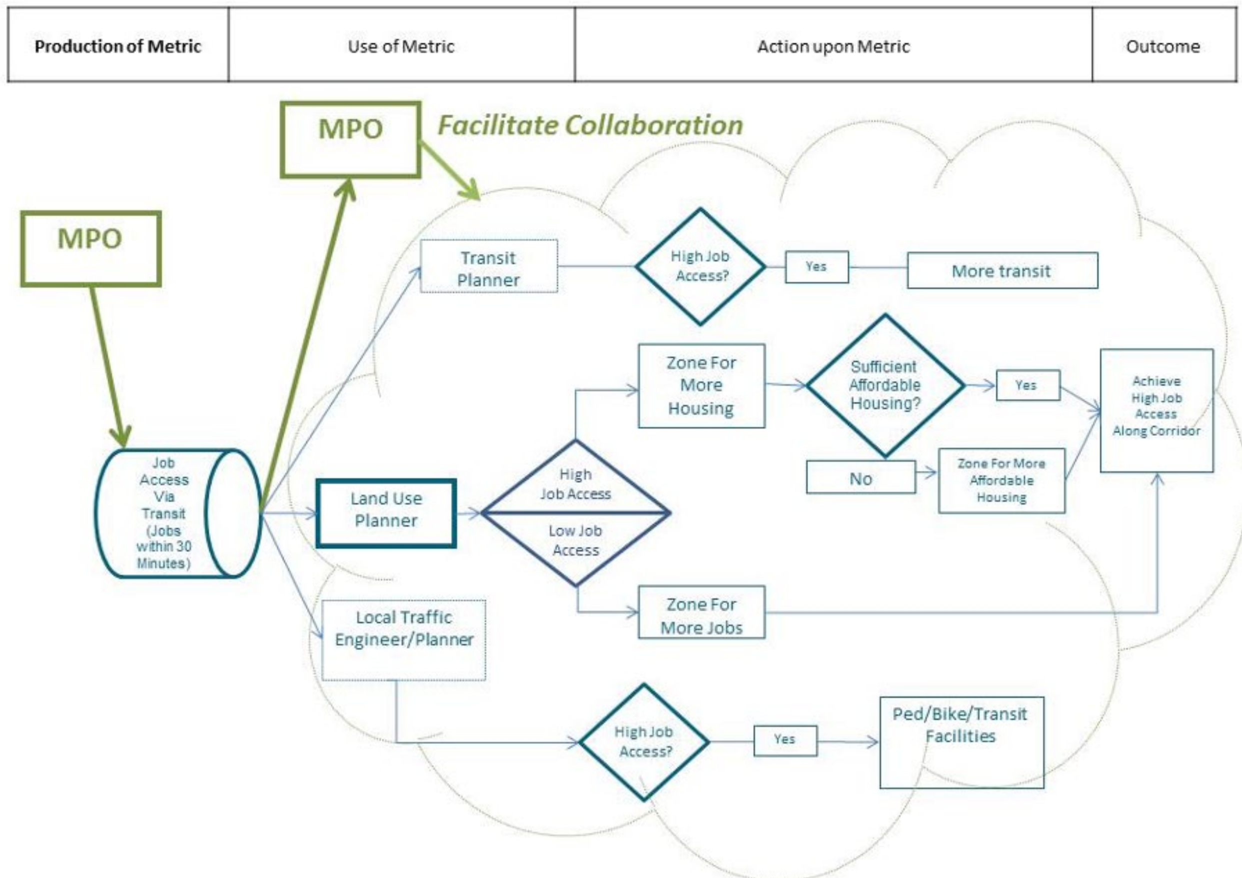

Figure 23. Conceptual Meta-View of the Ecosystem of Performance Measures, Their Production, and How They Can be Applied

WORKING WITH KEY PROFESSIONALS: JOINT STAKEHOLDER MEETING WITH SANDAG AND CALTRANS

On June 4, 2019, a joint stakeholder meeting between SANDAG and Caltrans Headquarters and District 11 Staff was held to present the above discussion of place types, frameworks, and how tools, including the Smart Mobility Calculator, could be used to better coordinate transportation and land use for sustainability, livability, and equity (SLE) outcomes.

Figure 24. Joint Stakeholder Meeting with Caltrans and SANDAG

Attendees:

Phone/ Conference call

Greg Martin

Ann Fox (Caltrans)

Tyler Monson (Caltrans)

Barbara Valentine (Caltrans)

+1 other

In Person/room

Allison Wood

Krystal Ayala

Marissa Meghan

Tracy Forshaw

Rachel Cortez

David Flight

Pat Landram

Dave Kedrow

There was general consensus in this meeting about the lack of coordination between land use and transportation that both Caltrans and SANDAG have to deal with. One participant lamented SANDAG's lack of land use authority, and that some cities don't want to "play ball." Sentiments were also expressed that both MPO and member agencies get penalized in California for not meeting climate goals.

There was general agreement and support that the tools and frameworks presented could help the coordination of transportation and land use planning by MPOs and Caltrans, working in partnership with local land use authorities.

Specifically, the following points were made:

- It is helpful to communicate the benefits to the public—and make economic arguments for different scenarios.
- If areas are shown to change their urban form (increase density, adding transit lines), showing the VMT/Transit/Health metrics is useful to show the public.
- The transparency provided by the SM Calculator is useful in working with all stakeholders.

- The SM Calculator is useful in how it allows you to draw corridors, then output these ballpark figures on sustainability, livability, and equity.

- Another useful feature would be to show scenarios with things like added transit lines, and then using the calculator to calculate changes in ridership/VMT/etc.

This feedback shows how transportation and land use coordination is an identified issue that needs to be addressed by Caltrans and MPOs working with local governments who have authority over land use. The Smart Mobility Calculator was also appreciated for its accessibility to a wide range of users and for how it can be used for corridor planning, especially in the early stages.

According to Caltrans' own official review of the Smart Mobility Calculator:

- The Calculator has very good functionality to show the Daily VMT (Per Capita, Per Employee, Per Capita for Home Base Work) which is helpful for Climate Action Planning, and evaluating the Environmental Impacts of development projects under SB 743. It uses Caltrans' official VMT numbers (per capita and per employee) that can be used to guide policies for Caltrans and its partners.

- By showing how much an area's VMT is above or below the regional average, the Calculator can be used to apply SB 743 CEQA project analysis parameters (which allows for environmental streamlining of significant developments at or below -15% of the regional average).

- In addition to VMT, the Calculator includes a number of other urban quality metrics related to environmental impacts, affordability, health, and social equity. Included metrics are Housing and Transportation Affordability, Dwelling Density, Population Density, Job Density, Carbon Emissions, Pedestrian Collisions, Job Accessibility, Walkability, Walking Percent, Obesity, and Cardiovascular Disease.

- Climate action planning: The tool shows how many pounds of carbon per household will be generated from travel in different locations in the region and can be used to calculate different development scenarios.

- New housing initiatives: This tool can help new housing initiatives (such as SB 50) by showing the areas that are in close proximity to transit. The circles show half mile catchment areas around transit stations using the high (green), medium (yellow), low (red) smart growth performance typology, based on a national study of urban quality of the National Academies of Sciences.

- It also shows the location of disadvantaged communities, per SB 535, which is key to then being able to inform communities they should enact community planning processes to handle new growth and avoid displacement that could come with gentrification.

VIII. CONCLUSION

Performance measures and planning support tools are useful only insofar as they help inform agency decisions about future policies, plans, and investments. In particular, performance measures should be defined and measured in order to help communities understand tradeoffs and benefits toward achieving sustainability, livability, and equity outcomes. Most regions continue to use transportation system performance measures that are dominated by congestion and mobility measures, although this is now changing in California with initiatives like SB 743.

A major purpose of this report is to help agencies make better, more coordinated transportation and land use decisions. While it would be ideal to have transportation and land use decisions all made by one agency, they are currently led by different agencies operating at different scales and time frames. Therefore, we are left to develop frameworks and tools to better measure, understand, and then act to realize sustainability, livability, and equity. The corridor level is an ideal scale where transportation and land use agencies can work together. Departments of Transportation like Caltrans should embrace their role as ambassadors to work with local land use authorities to organize efforts at the corridor scale. To be effective, all parties should adopt a broader, more empathetic understanding for each other's perspective and use the tools and measures collectively, as can be done with the Smart Mobility Calculator. If both sides of the transportation and land use equation start to work with each other's perspective, tools, measures and policy perspective, then we have a better chance of achieving sustainable, livable and equitable outcomes. As travel is a derived demand to get from one place to another, it is helpful to remember that a good regional land use plan can be a great regional transportation plan.

In summary, these frameworks and tools should be employed to:

1. Create context-sensitive and inclusive processes to help stakeholders and a community understand what it takes to become more sustainable, livable, and equitable;

2. Help understand what is important to measure and analyze in current conditions and future scenarios;

3. Screen, prioritize, and mediate policies in support of increasing a diverse and complementary set of opportunities for people to realize greater community sustainability, livability, and equity; and

4. The tools should be clear, intuitive, and relevant to the stakeholders using them.

APPENDIX

GOING FORWARD: A FRAMEWORK FOR MEASURING, UNDERSTANDING, AND REALIZING TRANSPORTATION AND LAND USE COORDINATION

The recommendations in this Appendix build on the authors' review of work on the SMF Implementation Process for the SBCC, Caltrans, LA Metro, and SCAG, and their respective CSPP/SMF processes.

In sum, informing agency decisions should be the driving force behind measures, approaches, study areas, etc. A major purpose of this work is to help agencies make better, more integrated transportation and land use decisions. While it would be ideal to have transportation and land use decisions all made by one agency, they are led by different agencies operating at different scales and over different time frames. Therefore, it is important to discuss ways to integrate these decisions through the existing processes of the institutions and their various measures. But first, it is necessary lay some groundwork regarding how we should think about performance measures.

Understanding the Various Roles of Performance Measures

When considering the use of performance measures in transportation and land use planning, there are a few aspects that should be considered: What? Why? and finally, Who?

"What?" refers to "what do the measures tell us?" including their *associations*, *causal relationships*, and the *context* that they convey.

Associations and Causal Relationships

Basically, what do the measures communicate? In other words, what can be established either from the body of empirical research, or from theory about the *association* that measures have to policy, as well as to each other? For example, research tells us that regional accessibility/ centrality is often associated with lower VMT and vehicle use (Ewing and Cervero, 2010 and 2010b)update earlier work, include additional outcome measures, and address the methodological issue of self-selection. Methods: We computed elasticities for individual studies and pooled them to produce weighted averages. Results and conclusions: Travel variables are generally inelastic with respect to change in measures of the built environment. Of the environmental variables considered here, none has a weighted average travel elasticity of absolute magnitude greater than 0.39, and most are much less. Still, the combined effect of several such variables on travel could be quite large. Consistent with prior work, we find that vehicle miles traveled (VMT. *Associations* can also refer to which measures interact with each other (see example below).

Context (Place Type)

This means asking questions about the environment and scale, including built form, the transport facilities (e.g., street design, light rail facility, freeway), socio-demographics, and so on. Basically, what type of place are we talking about?

As an illustration, combining *Associations* and *Context* can indicate that if an area has a high centrality rating, one should expect lower VMT. If this is not the case, then something is missing: perhaps the facilities for non-auto travel. This is critical, as many of even our best scenario planning models and tools do not do much in the way of appreciating new facilities for bicycles, pedestrians, or even such new modes as neighborhood electric vehicles. The MXD model developed by Ewing et al. (2013), for example, is limited to measuring intersection density, which—while effective—is a rather coarse measure of pedestrian/bicycle facilitation (Ewing et al., 2011).

"Why?"

This question essentially refers to the purpose of the measure. Once the *Associations* and the *Context* within which these measures are being applied are understood, the next aspect to be considered is for what *Purpose* the measures will be used.

What is the measure going to be used for? What are the purposes of the measure? There are at least four purposes for which a measure can be used, as follows:

- Benchmarking/assessment (diagnosis)
- Policy decision making (prognosis)
- Forecasting
- Monitoring

"Who?"

Finally, perhaps the most important element for implementation is asking who the best agencies are to generate, disseminate, and/or act upon these measures. Who are the agencies and stakeholders who will use these data, and what is the decision ecosystem in which the measures could be applied? The following are common stakeholders and their areas of interest:

- **Transportation agencies** are concerned with access along corridors generally and have specific concerns relating to transit ridership levels, capital investment decisions, and ongoing operational decisions across various modes at the local and regional scale.
- **Municipal governments** set land use designations and standards for private development and also have direct authority over local streets and infrastructure. Municipal policies further relate to housing, economic development, and other dimensions of livability.
- **State departments** have the responsibility for complementary policies pertaining to transportation, housing, the environment, economic development, and social services.

- **Private developers** and business interests deliver most non-government investments, including most forms of development within regulatory limits and procedures.

- **Advocacy groups** represent an array of concerns that may focus on a locale (for example, community groups) or a specific interest (such as affordable housing or bicycling).

- **Community members** who live or work in the areas are central stakeholders, regardless of whether they are represented by an organization.

Building on the above is a discussion, here is a set of performance metrics that were recommended for this project. First, they were based on the SMF performance measures and compared to the performance measures used by Metro in the Long Range Transportation Plan (LRTP) as well as by SCAG for the RTP/SCS. In selecting the performance metrics, the intent was to identify a subset of the SMF measures that would be most meaningful in demonstrating the sustainability policies at the sub-regional scale. The authors' approach was built from the six overarching SMF Principles. They are as follows:

- Location Efficiency

- Reliable Mobility

- Health and Safety

- Environmental Stewardship

- Social Equity

- Robust Economy

Alongside these principles were 17 SMF performance measures and their recommended metrics, as described in Exhibit 11 of the Smart Mobility 2010: Call to Action.

The authors' initial assessment was that these SMF measures require that significant planning analysis infrastructure (e.g., regional travel demand models) already be in place (and accessible) to support the computation of all 17 performance measures, and SMF requires significant investment of professional effort to perform the computations for a variety of possible transportation improvement projects.

Below are the principles from the CSPP and the SBCCOG.

CSPP principles:

- Connect people and places

- Create community value

- Conserve resources

SBCCOG Sustainable South Bay (SSB) principles:

- Reduce criteria pollutants
- Reduce congestion
- Reduce gasoline consumption
- Improve safety

The specific metrics that are recommended below are intended to be supportive of these principles as well as the overarching principles of the Smart Mobility Framework.

The CSPP uses 15 performance measures in support of the three broad CSPP principles to evaluate projects. Performance measures from CSPP are used for monitoring purposes at the regional level rather than for evaluation or prioritization, but some of them could be appropriate for sub-regional analysis. Additional project-based metrics were developed through consultant efforts related to the CSPP; these are meant to be used to compare the performance of different project alternatives rather than to compare and prioritize different projects as part of a sub-regional planning effort. Table 1 lists the metrics used by the CSPP and the SBCCOG.

In addition, the SBCCOG has identified several strategies for sustainable development that would not generally score very well using traditional performance measurement packages, which are often focused on measuring increased system performance for automobiles.

Table A1 summarizes the recommended performance metrics, tools, and data sources.

Table A1. Recommended Performance Metrics

Performance metric	Principles: CSPP — Connect	CSPP — Create Community	CSPP — Conserve	South Bay Cities — Reduce Pollutants	South Bay Cities — Reduce Congestion	South Bay Cities — Reduce Gas Consumption	South Bay Cities — Improve Safety
Average proximity to employment (30 min by transit)	✓	✓					
Average proximity to employment (20 min drive)	✓	✓					
Average vehicle occupancy (AVO)			✓	✓	✓	✓	
Modal travel time and cost	✓						
NEV, bicycle, walking facilities	✓		✓	✓	✓	✓	✓
Percentage of trips by transit				✓	✓	✓	
Percentage of trips by NEV				✓	✓	✓	
Percentage of trips by bicycling				✓	✓	✓	
Percentage of trips by walking		✓		✓	✓	✓	
Quantities of criteria pollutants and GHGs			✓	✓		✓	
Vehicle hours of delay (VHD) or person hours of delay			✓	✓	✓		
Vehicle miles traveled (VMT) or person miles traveled			✓	✓		✓	
Vehicle hours traveled (VHT)			✓		✓	✓	✓
VMT per capita by speed range			✓	✓		✓	
Number of crashes							✓
Number of vulnerable user crashes							✓

Further Review of Online Planning Support Tools

The California Healthy Places Index aggregates health-related information about census tracts in California and integrates them (along with other health indicators) into an HPI (Healthy Places Index) score. The map is unique in that multiple individual health or non-health metrics can be overlaid on the base map, allowing for quick assessment of individual metrics' influence on the overall HPI score. The map has a well-defined color scheme and outlines census tracts that the mouse hovers over, along with a quick reference for determining the score range of a certain color.

The CNT's H + T Index tracks housing and transportation costs as a percentage of income for searched locations, with a wide range of granularities ranging from Metropolitan Planning Organization level to Census Block Group level. The index not only visually presents

ABBREVIATIONS AND ACRONYMS

CSPP	LA MTA's Metro Countywide Sustainability Planning Policy
DOT	Departments of Transportation
EPA	Environmental Protection Agency
HH	Household
LA MTA	Los Angeles County Metropolitan Transportation Authority
MPO	Metropolitan Planning Organization
SBCCOG	South Bay Cities Council of Governments
SCAG	Southern California Association of Governments
SMC	Smart Mobility Calculator
TLC	Transportation and Land Use Coordination
VMT	Vehicle Miles Traveled

affordability data in a map, but also presents information graphically and as a percentiles chart. Data at any granularity can be accessed as a “fact sheet” that highlights important metrics and factors that influence the overall level of affordability. The online map quickly provides an affordability number for quick assessment, but the detailed information behind affordability is easily downloaded and provided in a visually appealing and readable format.

All of the maps discussed above are successful in conveying a large quantity of information quickly and easily for the viewer. The Opportunities Atlas relies on separating metrics allowing the viewer to see one set at a time in a non-overlapping manner. On the other hand, the California Healthy Places Index aggregates information into a single index which can then be easily seen on a map. Somewhere along the spectrum of information display is the H + T Index, which is data-intensive but offers a level of detail the viewer determines. However, none offer tools to sort data and search based on other pieces of information besides location, nor do they have integrated mechanisms for scenario planning exercises. Some example tools may include: optimal location selection for a given set of parameters, visual data comparison between multiple locations, or location ranking based on data. Additional decision making capabilities are likely beyond the primary purpose of the online maps.

ENDNOTES

1. Planning support tools (also called planning support systems) are computer-based applications that assist in urban planning activities by providing access to essential data, models, and spatial analysis methods (Geertman and Stillwell, 2004).

2. The report was actually entitled *Our Common Future* and was produced by the World Commission on Environment and Development, but it is best known by this title.

3. Some call these the three Es, with the social component being referred to as social *e*quity.

4. Ibid.

5. There are several specific works that show conceptual agreement on defining sustainability in transportation, as follows:

   - Black, W. "Sustainable Transport: Definitions and Responses." Integrating Sustainability into the Transportation Planning Process. 2005.

   - Litman, T. and D. Burwell. "Issues in Sustainable Transportation." *International Journal of Global Environmental Issues* 6 (2006): 331–347.

   - Zhou, J. Sustainable Transportation: Review of Proposals, Policies, and Programs 2000–2007. 88th Annual Meeting of the Transportation Research Board. Washington, DC, 2009.

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https://www.elsevier.com/books/livable-streets-20/appleyard/978-0-12-816028-2

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