Strategic Issues Facing Transportation, Volume 4: Sustainability as an Organizing Principle for Transportation Agencies

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 750

Strategic Issues Facing Transportation

Volume 4: Sustainability as an Organizing Principle for Transportation Agencies

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Lori L. Sundstrom
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This report provides state departments of transportation (DOTs) and other transportation agencies with an analytical framework and implementation approaches to assist them in evaluating their current and future capacity to support a sustainable society by delivering transportation solutions in a rapidly changing social, economic, and environmental context in the next 30 to 50 years. This report will be useful to senior transportation agency officials and policymakers who are positioning their agencies for continued relevancy in an uncertain future.

Major trends affecting the future of the United States and the world will dramatically reshape transportation priorities and needs. The American Association of State Highway and Transportation Officials established the NCHRP Project 20-83 research series to examine global and domestic long-range strategic issues and their implications for departments of transportation (DOTs) to help prepare the DOTs for the challenges and benefits created by these trends. *NCHRP Report 750: Strategic Issues Facing Transportation, Volume 4: Sustainability as an Organizing Principle for Transportation Agencies* is the fourth report in this series.

Increasing awareness of the environmental, economic, and social effects of the transportation system has already led to new demands on transportation agencies to be more responsive in providing transportation services. Transportation agencies are challenged to build consensus around balancing short-term cost effectiveness and long-term sustainability. While the roles and responsibilities of transportation agencies differ from state to state, there are common organizational attributes and characteristics that transportation agencies need in order for their transportation systems to support the environment, the economy, and social equity.

Under NCHRP Project 20-83(7), Booz Allen Hamilton was asked to develop an analytical framework for transportation agencies to use to identify and understand the future trends and external forces that will increasingly put pressure on their ability to carry out their responsibilities to meet society's evolving demand for transportation services while also meeting society's emerging need to operate on a more sustainable basis. The research (1) identified likely alternative future scenarios in which transportation agencies could be asked to achieve sustainability goals of the triple bottom line of economic vitality, social equity, and environmental integrity under conditions 30 to 50 years in the future; (2) analyzed how transportation agencies' existing fiscal, legal, and institutional structure(s) and decision-making processes encourage or inhibit them from optimizing their contribution to a sustainable society; (3) examined the variety of roles, and the nature of their related primary activities, that transportation agencies may be expected to play in the future; (4) explored

linkages, and expectancies, between transportation agencies and stakeholders, and the need to form new alliances and partnerships with other transportation providers and system users; and (5) provided tools that individual agencies can use in designing their particular approach(es) to adapt to the demands and opportunities of the future and in describing, in broad terms, how "sustainable" transportation agencies might be organized.

Against a backdrop of changing societal expectancies related to transportation, the traditional functions of many transportation agencies are changing. As they evolve, transportation agencies will have to be resilient in the face of continuing and new demands by society, and they may need to fundamentally rethink the mission(s) and organizing principle(s) that drive them today.

CONTENTS

ACRONYMS AND INITIALISMS

AASHTO	American Association of State Highway and Transportation Officials
ACEC-Illinois	American Council of Engineering Companies–Illinois
AFV	Alternative Fuel Vehicle
AI	Artificial Intelligence
AIChE	American Institute of Chemical Engineers
APWA	American Public Works Association
ASCE	American Society of Civil Engineers
ASTRA	Assessment of Transportation Strategies
BBB	Balanced-Base Budgeting
Caltrans	California Department of Transportation
CART	Conservation and Alternative Resource Team
CBA	Cost–Benefit Analysis
CCA	Cross-Consistency Assessment
CEQ	Council on Environmental Quality
CMAP	Chicago Metropolitan Agency for Planning
CO2e	Carbon Dioxide Equivalent
COG	Council of Government
COTS	Commercial off-the-Shelf
CREATE	Chicago Region Environmental and Transportation Efficiency Program
CSS	Context Sensitive Solutions
CST	Centre for Sustainable Transportation
CTA	Chicago Transit Authority
CTP	California Transportation Plan
DEQ	Department of Environmental Quality
DGC	Durable Goods Calculator
DLCD	Department of Land Conservation and Development
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DSD	Division for Sustainable Development
EEA	European Environment Agency
EFCA	Environmental Full Cost Accounting
EJ	Environmental Justice
EPA	Environmental Protection Agency
EPI	Environmental Performance Indicator
ESCOT	Economic Assessment of Sustainability Policies of Transport
EU	European Union
FCA	Full Cost Accounting
FEMP	Federal Energy Management Program
FHWA	Federal Highway Administration

GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GMA	Growth Management Act
GreenLITES	Green Leadership in Transportation Environmental Sustainability
GTAP	Global Trade Analysis Project
HBN	Healthy Building Network
HDM	Highway Design Manual
HEAT	Highway Economic Assessment Tool
HOV	High-Occupancy Vehicle
HUD	Housing and Urban Development
I-LAST	Illinois–Livable and Sustainable Transportation
IMPLAN	Impact Model for Planning
INDOT	Indiana Department of Transportation
INVEST	Infrastructure Voluntary Evaluation Sustainability Tool
IPCC	Intergovernmental Panel on Climate Change
IRTBA	Illinois Road and Transportation Builders Association
ISI	Institute for Sustainable Infrastructure
ISTEA	Intermodal Surface Transportation Efficiency Act
ITRC	Interstate Technology and Regulatory Council
ITS	Intelligent Transportation System
LCA	Life-Cycle Assessment
LCC	Life-Cycle Costing
LCCA	Life-Cycle Cost Analysis
LCEA	Life-Cycle Cost Environmental Accounting
LEED	Leadership in Energy and Environmental Design
LOS	Level of Service
LRTP	Long-Range Transportation Plan
MA	Morphological Analysis
MAM	Macroeconomic Activity Module (part of NEMS)
MDOT	Minnesota Department of Transportation
MDSHA	Maryland DOT
Metro	Portland's Metropolitan Planning Organization
MPO	Metropolitan Planning Organization
MTA	Metropolitan Transit Authority
MTC	Bay Area Metropolitan Transit Commission
MTR	Mountain Top Removal
NASCAR	National Association of Stock Car Auto Racing
NCHRP	National Cooperative Highway Research Program
NEMS	National Energy Modeling System
NEPA	National Environmental Policy Act
NHS	National Health Service
NIMS	Not-in-My-System
NRDC	Natural Resources Defense Council
NRTEE	National Round Table on the Environment and the Economy (Canada)
NYSDOT	New York State Department of Transportation
NZ$	New Zealand Dollar
NZME	New Zealand Major Events
O&M	Operations and Maintenance

ODOE	Oregon Department of Energy
ODOT	Oregon Department of Transportation
OECD	Organization of Economic Co-operation and Development
OMB	Office of Management and Budget
OPB	Oregon Progress Board
OPEC	Organization of Petroleum Exporting Countries
ORTEE	Ontario Round Table on Environment and Economy
OSTI	Oregon Sustainable Transportation Initiative
P3	Performance Programming Process
PlaNYC	New York City's multidimensional, interagency plan
PRISM™	Parsons Brinckerhoff Regional Impact Scenario Model
READ-Database	Directory Database of Research and Development Activities
REMI	Regional Economic Models, Inc.
ROI	Return on Investment
RPA	Regional Plan Association
RPO	Regional Planning Organization
SB	Senate Bill
SFMTA	San Francisco Metropolitan Transportation Authority
SIA	Sustainability Impact Assessments
SLCA	Sustainability Life-Cycle Accounting
SMARTe	Sustainable Management Approaches and Revitalization Tools–electronic
SMCRA	Surface Mining Control and Reclamation Act of 1977
SME	Subject Matter Expert
SMF	Smart Mobility Framework
SOV	Single-Occupancy Vehicle
SROI	Sustainability Return on Investment
STARS	Sustainable Transportation Access Rating System
STPI	Sustainable Transportation Performance Indicators
TAC	Transportation Association of Canada
TBB	Target-Based Budgeting
TBL	Triple Bottom Line
TCA	Total Cost Accounting
TEA-21	Transportation Equity Act for the 21st Century
TERM	Transport and Environment Reporting Mechanism
TIGER	Transportation Investment Generating Economic Recovery
TOD	Transit-Oriented Development
TRB	Transportation Research Board
TTPO	Tribal Transportation Planning Organization
TxDOT	Texas Department of Transportation
USDOT	U.S. Department of Transportation
VMT	Vehicle Mile Traveled
VTPI	Victoria Transport Policy Institute
WARM	Waste Reduction Model
WCED	World Commission on Environment and Development
WSDOT	Washington State Department of Transportation
ZBB	Zero-Based Budgeting

SUMMARY

Sustainability as an Organizing Principle for Transportation Agencies

Research Approach Overview

The research for National Cooperative Highway Research Program (NCHRP) Project 20-83(7) followed a systematic process of defining key terms and concepts, forecasting plausible future scenarios, performing present–future gap analysis, assessing near-term tools, and providing methods and recommendations for transportation agencies to monitor progress toward a sustainable society and to prepare to effectively support that policy system.

The research and analysis in this report achieves the following goals:

- Defines sustainability and its organizing principles, and assesses the current progress and ability of transportation agencies to support a sustainable society
- Presents literature review and thought-leader interview findings on current sustainability-related practices and initiatives
- Postulates and assesses the key gaps between present-day agency functions and those that would most likely be needed in a future sustainable society setting
- Presents multiple plausible future scenarios and identifies future opportunities and challenges that transportation agencies would encounter in a sustainable society setting under each of the scenarios
- Provides recommendations on near-term actions, and tools and methods to be developed to prepare to support societal sustainability in the future

Key limitations on the scope of this research report are as follows:

- This report is not intended to address sustainable transportation; rather, it focuses on how transportation agencies can best support a sustainable society.
- This report is not intended to recommend specific policies, programs, or guidelines that can be followed to deliver a more sustainable society or sustainable transportation; instead, it focuses on the factors affecting the capabilities of transportation agencies to support a sustainable society and how this capability can be improved given future scenarios.
- This report provides recommended strategies and methods to help transportation agencies anticipate evolution of a triple-bottom-line (TBL) sustainability policy system[1] and to act in the near term to prepare transportation agencies to best support a sustainable society in the future.
- This report focuses primarily on state transportation agencies; however, it does address how regional, local, and federal transportation agencies may be involved in future sustainability-related programs.

[1] A policy system that is intended to manage and preserve an optimum balance in the value of economic, environmental, and social well-being for future generations.

Anticipating that audiences will include industry practitioners of various levels and disciplines, as well as academic researchers, the research was guided by the intent to support all of the findings, opinions, theory, logic, and case experience to the fullest practical extent in the report—so that all audiences may find the explanations and sources they need for the material to be useful.

This research is not intended to advocate or to predict that sustainability *will* become a viable overarching organizing principle for transportation. Rather, the work is intended to consider how transportation might best support a *sustainable society* in the future—and to examine what the implications for the transportation community might be *if* sustainability is adopted as an organizing principle for transportation agencies. This research is forecasting the environments that state departments of transportation (DOTs) may find themselves in between 2030 and 2050.

The research addresses multiple topics for which precedent and experience are lacking. Actual experience with the managed achievement of a TBL sustainable society is nonexistent. Additional challenges for the research included the following:

- **Predicting a distant future.** This is impossible to do with precision and detail. To cover the possibilities, the research team developed a set of plausible futures using logical projections of the key drivers that are likely to affect social, economic, and environmental conditions. However, because the team cannot foresee the "expected unexpected," the details of each projection are somewhat speculative and debatable.
- **Defining sustainability in programs and literature.** The term "sustainability" is used in multiple ways in industry, and it frequently refers to initiatives that focus on sustainability of particular operations or projects, enhancing or preserving a single bottom line—usually the environment. This report uses "TBL" when "triple-bottom-line" sustainability is intended.
- **Applying economic and social theories to long-term demographic effects.** With much of the infrastructure and jurisdictions fixed, significant demographic shifts (even gradual ones) can present governance, management, resource, and TBL policy challenges to agencies at all levels.

Defining Sustainability and Key Assumptions

There are many popular definitions of sustainability in use today. The research team has based its working definition on the report of the Brundtland Commission, *Our Common Future*, which provides a now well-accepted definition of sustainable development: "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).

NCHRP Report 708: A Guidebook for Sustainability Performance Measurement for Transportation Agencies provides guidance for state DOTs and other transportation agencies to understand and apply measures and concepts of sustainability. This guidance also contrasts sustainable development and the broader concept of TBL sustainability. The basic thrust of the Brundtland definition is generational equity (achieved through consideration of the TBL), which is a reasonable definition to apply to sustainable society. Sustainability calls for consideration and balance of three policy dimensions—economic, social, and environmental—the elements of the TBL. The research team used "TBL" as an appropriate descriptor for this concept in the research and adopted some additional key assumptions:

- **TBL focuses on the long term rather than the short term:** The key requirement of sustainability is to allow fulfillment of present as well as future needs; present and future needs fulfillment must occur for development to be sustainable.

- **TBL is an integrated rather than a stand-alone concept:** TBL is not exclusive to any one policy area or system. Given the integrated nature of transportation with the rest of human activity, it is difficult to view the transportation system in isolation. Sustainable transportation requires considering a broad definition of sustainability that considers how transportation affects overall social sustainability and how other policy areas need to be coordinated to achieve sustainability.
- **TBL is multidimensional:** The three TBL dimensions do not represent clearly distinct compartments; rather, they provide ways to systematically view the interlinked character of societal development as it draws on environmental, economic, and social resources and mechanisms. Development along the TBL dimensions does not take place in a governance vacuum; it presupposes institutional arrangements and institutional reforms.

Society can work toward this concept with specific environmental, social, or economic improvement initiatives, but, to reach the goal of sustainable TBL, programs need to

- Provide for generational equity in society's well-being overall, per the Brundtland definition;
- Stand up to TBL challenges under a reasonable range of plausible future scenarios; and
- Be based on long-range logic and TBL decisions that yield discernible return on investment (ROI) along the three bottom lines to ensure public support.

TBL sustainability definitions depend fundamentally on the treatment of social, environmental, and economic stores of capital value to the public. The general definitions of the three stores of capital are found in the literature as follows: environmental capital is the value of the quality and health of the environment; social capital is the value of social conditions and the networks of relationships that support social needs; and economic capital is the value of economic growth to support and improve the health and welfare of a society. Presumably the total "value" of all three capital stores should be optimized (or maximized) for best overall societal well-being—provided the values of the three stores can be maintained in an acceptable balance or proportion to each other for future generations, as determined by local, regional, and/or national public will.

The long-range, broad risk/reward decisions and planning needed to address generational equity on a TBL scale are foreign to the shorter and mid-range perspectives of most decision-makers in both the public and private sectors. U.S. society can easily be distracted from sustainable TBL by pressing near-term issues or by the need for a narrow focus on a singular (albeit important) long-term challenge.

The latter challenge is perhaps why the U.S. policy system has been tilting toward emphasizing reductions in greenhouse gas (GHG) emissions. This is not to say GHG reduction is not a very big concern or that it does not go hand in hand with the need to reduce fossil fuel consumption. But by the policy system definition above, GHG abatement has passed through the "widely held belief" stage, and many agencies and interest groups are now working on the second stage (policy and measurement) in the United States and overseas. The research team took some perspectives from the GHG case to inform this research on how a future sustainable TBL policy system may evolve.

In practice, the term "sustainability" is used very loosely. It is used most often in reference to objectives connected primarily to one of the three bottom lines, or to specific assets or processes such as "sustainable business" or "sustainable hotels." This usage has complicated the dialogue about and understanding of practices that apply to a sustainable TBL society.

Transportation asserts an enormous effect on all three elements of the established view of TBL sustainability producing both benefits and impact:

- The **economy** is highly dependent on the readily accessible and efficient movement of people and commerce, but the economy is also very sensitive to availability and cost of

resources—and transportation consumes about a quarter of all the energy used in the United States.
- **Social** well-being depends heavily on accessible and efficient transportation services; however, extensive fixed infrastructure and operations that intrude on quality of community life strongly affect social well-being. Effective transportation planning and development practices can mitigate or resolve many of these issues.
- The **environment** does not benefit in many ways from transportation; at the same time, transportation agencies focus on compliance with environmental regulations and on initiatives to mitigate negative impacts and to enhance the environment where possible.

Defining "Organizing Principle" and "Policy System"

An "organizing principle" is a core assumption from which everything else can derive a classification or value. That is, an organizing principle is a central reference point or framework that allows all other concepts or values to be located in a single conceptual map. In terms of the design of organizations and decisionmaking structures, organizing principles sit above statements of specific goals or objectives, decisionmaking tools, and policies. Organizing principles represent a paradigm through which all aspects of a delivery system for a public good are considered.[2]

With a slightly broadened definition, an organizing principle is also commonly understood as a "policy system." A policy system encompasses the same policymaking and high-level functional components as does an organizing principle. A policy system includes more explicit overarching priorities at the top level, along with measurement systems and feedback to enable and inform policy. The overarching priority and the measurement concept resonate well with the past and present experience with evolution of organizing principles, or policy systems.

An evolving policy system:

- Starts with a strong, widely held belief in an overarching priority, concern, or concept;
- Builds on policy and measurement approaches that can support and inform policy and regulation; and
- Engages high-level functions to deliver on the priority and concept.

The concept of policy system change is highly relevant to this project. How transportation policy systems are influenced toward change and the processes for framing new policies are important to understanding the implications of supporting a sustainable society under different scenarios. Studies of policy system evolution and policy framing have shown that it is an important process that occurs in major policy debates (Gamson, 1992; Gamson and Modigliani, 1989; Gamson et al., 1992). Importantly, a policy frame can contain a range of positions on an issue. Individuals can share a common understanding of a policy frame while holding substantially different policy preferences. For example, two planners can accept the framing of transportation policy based on sustainability and perform the same analysis of a transportation issue but see different solutions. Transportation agencies will have to

[2] "Public goods" and "public services" in this sense generally refer to the goods and services provided by a government to its citizens. A government provides public goods and services directly (through the public sector); by financing private provision of services; or by implementing policies that encourage individuals, the private sector, and other groups to provide those goods and services. Where public goods and services are neither publicly provided nor financed, for social and political reasons they are usually subject to regulation.

adopt new policy frames that reframe the issue of transportation within a sustainability context and reach consensus with the public and specific policy actors within the process.

Policy systems have evolved in this way for generations. Early in U.S. history, transportation played an important role in opening up the country's resources and fueling the industrial revolution. Mobility then became a distinct policy system as it drove major transportation infrastructure development. As the infrastructure fueled growth, the U.S. policy system gradually evolved to respond to safety and environmental concerns that had generally been absent earlier. Those concerns were then met with the development of extensive regulation, further transforming the policy system focus to regulatory compliance. This regulatory policy system in turn led to a greater outcome-and-performance focus in the Intermodal Surface Transportation Efficiency Act (ISTEA) and Transportation Efficiency Act for the 21st Century (TEA-21) eras, while retaining the strong environmental compliance principles. Today a new policy system is evolving that seems to be focusing on nonrenewable resources and climate change concerns, though all levels of government have not yet embraced this system.

Policy systems can exist singly or in parallel in society, depending on the sector focus of the priorities or the concepts driving them. Policy systems evolve and decline as priorities strengthen and abate.

For this research, the team developed and characterized the evolution of transportation policy systems toward supporting a sustainable society. The evolution begins with the early policy system of the 1950s and 1960s (Safe Mobility), evolves through the end of the 20th century (Compliant Transportation) into the current decade (Green Transportation), and then evolves through a future sustainability-focused system (Sustainable Transportation) into the society sustainable (TBL Sustainability) policy system. These are summarized in Figure 1. Chapter 2 discusses the five identified policy system models in more detail.

The policy systems models depicted are thematic and apply to transportation as a whole. Not all transportation agencies and sectors adapt to aspects of these policy systems in the same way—or during the same time frame. Chapter 2 illuminates this point further. It describes the policy system models, as well as where various levels of U.S. government agencies and international governments appear on this spectrum. Level 2, Green Transportation, depicts the policy system model that many transportation agencies operate under today. Level 4 is conceptualized as the policy system model that would drive TBL sustainability in the future.

High-Level Functional Framework for a Policy System

To frame and structure an analysis of a future policy system based on sustainability, the research team determined to focus initially on the high-level functions that are common to federal, state, and local transportation policy systems. These high-level functions fall into three broad categories: governance and policymaking, decisionmaking, and enterprise management, as shown in Table 1.

These functions do not form a strict hierarchy; rather, they are the core functions that work to establish a policy system and deliver transportation products and services. The core functions are used in this report to enable systematic assessment of sustainability as an organizing principle—or basis of a policy system—for transportation.

The core functions do not necessarily imply specific activities vested in specific entities. Under any policy system, these core functions may be executed by one, some, many, or all

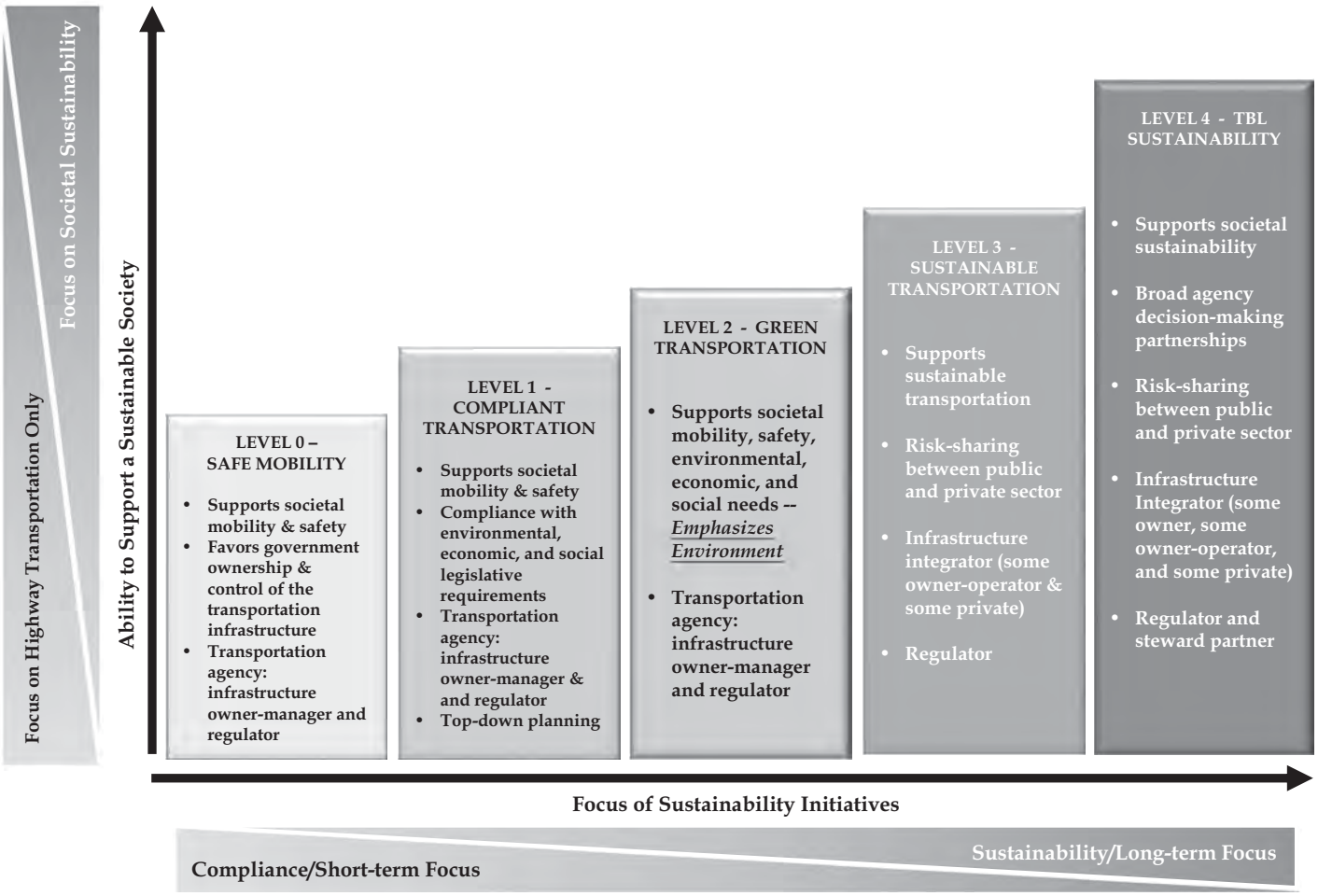


Figure 1. Past, present, and future transportation policy systems.

entities engaged in the business of transportation. Today, numerous entities structure and execute these functions to follow various policy systems (e.g., mobility, safety, economic development, environmental stewardship). The body of this report further describes and assesses the core functions.

The research team notes here that the future organizational aspects of a policy system can follow many structural schemata. The practical considerations of authorities, nature

Table 1. Functional framework for assessment of a future TBL policy system.

	Governance and Policymaking	Decisionmaking	Enterprise Management
High-Level Functions	Consensus on Needs and Goals	Planning and Programming	Service and Product Delivery
	Regulation and Rulemaking		
	Outreach and Communications	Budgeting and Resource Allocation	
	Compliance and Dispute Resolution		
	Education, Training, and Culture Change		

of tradeoffs and decisions, information to be processed, geography, and cross-sector and multimodal issues and strategies will ultimately drive the basic institutional, commercial, and government structures and relationships that make best sense at the time.

Key Research Findings

For this project, the research team performed an extensive literature review and interviewed subject matter experts (SMEs), thought leaders, and senior agency officials. Key themes from the interview process are summarized in Table 2. These themes reflect the opinions of multiple interviewees and therefore show some divergence of opinion.

Table 2. Key interview themes.

Theme	Supporting Opinions
Sustainability is a complex, challenging idea.	• Definitions are complex and ambiguous. • Some don't yet accept the concept and are uncomfortable with its connotations.
Understanding of and support for sustainability is increasing.	• The current trend is toward acceptance of the need for sustainability. • Transportation policy is increasingly integrating the concept of sustainability.
TBL needs a fiscal element.	• TBL needs to address sustainable fiscal capacity that provides financial resources in the future. • Long-term funding and support commitments are needed.
Social indicators are difficult to develop.	• Developing credible social indicators is challenging. • Cost of developing indicators is prohibitive and measures are difficult to apply.
The current trend is to wait for demand rather than to develop demand.	• The tendency is to wait for strong leadership from state or local leaders or the public. • Small modifications in the planning process can build constituency. • Waiting for public policy is not necessarily the best solution.
Sustainability cannot be an add-on; it must inform culture and process.	• Sustainability needs a total process and culture change. • TBL is outside the context of traditional transportation planning and engineering. • Performance standards should be used to influence change. • New internal processes and organization schemes are needed.
One size will not fit all.	• Case conditions vary so much that tailored, different solutions are needed. • A range of tools and accepted performance standards are needed. • Methods are needed to normalize different measures and indicators. • Scenario planning could be useful in planning for sustainability.
There is a need to build the business case for sustainability and show ROI.	• A comprehensive business case for sustainability is needed. • Appropriate ROI tools for sustainability do not exist in the United States.
Sustainability requires public involvement and stakeholder buy-in.	• Substantial stakeholder buy-in and continual public involvement is needed. • The concept is too far-reaching for the traditional public involvement process.
Localities can lead in sustainability initiatives.	• Localities influence land use, transit, user charging, and voters. • Modally focused agencies are more limited in flexibility. • Coordination of programs with modal agencies at all levels is needed.

The literature review aligned with the interview findings overall and added best practice information. Information from the review and interviews on specific subject areas and on transportation agency initiatives is provided in Appendix D. Highlights of this effort are as follows.

Sustainability Programs in State DOTs

Over half of state DOTs include sustainability principles in their mission statements, with most statements mentioning the need to balance economic, environmental, and quality-of-life concerns (data on this topic was collected from 2010 to 2011). However, no state has a legislatively authorized sustainable transportation program. It appears that at the state level there is a growing adoption of sustainability terminology but limited implementation of TBL programs. Interviewees and the literature review support the general principles of sustainability but note that, in some quarters, the term is polarizing and controversial—with resources stretched thin and state governments focusing on economic growth and job creation. A number of states have well-developed initiatives to address sustainability issues proactively, including development of rating systems and decision-support methodologies focused on planning, programming, project delivery, and operations. While social values and economic development issues are taken into consideration in some of these tools, the most direct focus is on evaluation of environmental effects.

Funding and Needs Assessment

There is a broad consensus within the transportation community that the current system of transportation funding is broken and that some form of user-charging strategy is needed to fund the future development and maintenance of federal, state, and local transportation systems (Committee for the Conference on Introducing Sustainability into Surface Transportation Planning, 2005). Technology, shrinking government budgets, and public hostility to across-the-board tax increases all make some form of user-fee strategy potentially appealing; however user-charging schemes of the type adopted in Singapore, Denmark, or other foreign countries have been difficult to implement in the United States.

Sustainability, Resource Allocation, and Intergenerational Equity

> "One of the key concepts in sustainability budgeting is that resource allocation must be flexible and resources allocated to achieve the optimal sustainable state consistent with the agency's project and mission. Thus, project funding should not be limited to specific funds or accounts. Rather, funding should be able to flow freely between accounts. Furthermore, sustainable resource allocation requires that budgeting and resource allocation not be limited to specific agencies, transportation modes, or geographic regions. Thus, transportation resource allocation and budgeting should be approached as a whole and resources allocated to achieve the optimal sustainable return" (Cutcher-Gershenfeld et al., 2004).

A major issue in accounting for the cost of programs or projects in the context of sustainability is the inclusion and evaluation of intergenerational equity and environmental justice. Research implies that consumption and economic well-being of the current generation should be limited in order to save resources and raise "the standard of civilization and culture" to a certain level. This would ensure that future generations would benefit from that accumulated TBL capital as well as any social/environmental benefits of de-emphasizing consumption.

Coordination and Planning

Coordination is a major challenge because it is multidirectional, that is, horizontal between different departments within the state government and vertical between different levels of

government. It was noted in interviews and from the literature review that unless state DOTs improve coordination of land use issues with local governments, there would be little hope of improving the sustainability of state transportation initiatives. States recognize this challenge but are limited in the extent to which they can manage land use issues. A number of states have attempted to develop programs that coordinate land use and sustainability, involving coordination with other state-level agencies and/or local governments.

Data and Performance Measures

Data and performance measurement are vital to sustainability management and to communicating complex decisions to legislators and to the public. About 60 percent of state DOTs use performance measures or indicators that are related in some way to sustainability—that is, they mention the environment, economy, and/or quality of life—and approximately 20 percent of DOTs use similar indicators for project prioritization. The use of "green" transportation standards for transportation investments is a closely related topic. Several states have developed rating systems modeled after the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system for buildings. In general, there is substantial data available on environmental and economic indicators, but it is more difficult for state DOTs to develop and agree on meaningful indicators of quality of life. Some states have tried to develop these indicators (e.g., Arizona, Delaware, and California) but have experienced considerable difficulty in narrowing down the list of meaningful leading indicators.

Culture Change, Outreach, and Communication

Sustainability will require substantial culture change, both within agencies and among public and state leaders. Widespread public support will be needed to drive legislation, policy, and executive orders. Given the current fiscal and economic climate, many agencies lack legislative, executive, and even public support to engage in new initiatives; most are focused on ways to save money and provide more efficient service delivery rather than on long-term benefits that are difficult to demonstrate. There is a need for TBL-based ROI tools to develop and communicate strong and credible business cases for sustainability.

Local Government Sustainability Programs

Most of the sustainability literature indicates that cities and local governments are well positioned for leadership in government sustainability initiatives. Cities experience problems and challenges that often require close integration of economic, environmental, and social policies and ready access to key stakeholders helps in developing consensus for action. Control or influence over land use decisions provides leverage to implement sustainability policy. Through a concentrated footprint, cities' economic and transportation needs are more uniform (than most states), somewhat simplifying transportation policy alternatives.

Trends in Local Government Sustainable Transportation Programs

Sustainability programs in several large and medium-sized cities were reviewed, and the research team found that programs tend to integrate a range of public services, rather than just transportation. If a local government initiates a Smart Growth program that requires changes in land use and zoning, it will inevitably require coordination from water and waste management authorities, school departments, and other agencies that need to be included

in coordinated land use planning. This leads to better integration of transportation planning with societal needs, including opportunities for recreation and social interaction, and accessibility for children and the poor. Managing a transportation mission within a larger decisionmaking and funding framework requires a supportive organizational culture, an agency structure, and planning structures that integrate sustainability culture. No matter what size the community, transportation funding has remained an issue. Local and state governments have used a variety of low-cost options to encourage people to use sustainable services (e.g., use of information technology to alert commuters to train times). Major transit programs require significant new taxes (e.g., Northern Virginia's business metro tax), bond issues, or coordination with state and federal efforts. Initiatives are also funded out of local use charges, including parking, tolls, taxes, and bonds.

Federal Sustainability Programs

Federal sustainability programs are developing and expanding, deriving their authority from a series of executive orders (FedCenter.gov, 2012). To date, these orders have focused primarily on internal federal agency priorities and operational efficiency, energy use, and GHG reduction. Executive orders have established a federal environmental executive, required agency senior sustainability officers, chartered an interagency steering committee on federal sustainability, and required agency-specific strategic sustainability performance plans. There are also a range of federal programs to assist communities, states, and the private sector in developing sustainability programs. The federal government has also invested in the development of various tools and resources to assist the public and private sector. These resources included Building for Environmental and Economic Sustainability (BEES 4.0), the Chartered Institution of Building Service Engineers (CIBSE), Sustainability Tool Earth 911 Reuse and Recycling Services, the U.S. Environmental Protection Agency's Regional Vulnerability Assessment Program, various GHG impact assessment tools, the U.S. General Services Administration's Sustainable Facilities Tool, READ-Database, and Sustainable Management Approaches and Revitalization Tools-electronic (SMARTe).

Sustainability Programs and Policies in Other Countries

A number of other countries have developed strong sustainability and sustainable transportation programs and policies. Although differences in institutional relationships; political systems; and economic, demographic, and land use patterns limit the value of international comparisons, they nevertheless demonstrate potential techniques or approaches that could be adapted to the U.S. context. New Zealand, widely regarded as a sustainable transportation leader, is at the forefront in developing a coordinated national policy for sustainability. The 2008 New Zealand Transport Strategy integrated transportation and climate change into a single sustainability program. This program has special mention here, because (1) the targets are statutorily enforced through the Government Policy Statement on Land Transport Funding, which establishes short-term system goals that will be achieved by prioritizing funding over the next 6 to 10 years, and (2) the New Zealand Transport Strategy will also be evaluated through a Transport Monitoring Indicator Framework, which is being made available to the public via an online interactive version.

High-Level Conclusions from the Research

A number of overarching conclusions can be drawn from the research and analysis documented throughout the report.

The current policy system is far from able to support a TBL sustainable society.

The U.S. overall policy system and institutional framework today is not yet capable of making the strategy, policy, and funding decisions that are truly driven by TBL considerations. It cannot, as a practical matter, even *consider* generational perspectives in a concrete, data-driven way today. The research team framed the future scenario conditions and characteristics of TBL sustainability policy systems and found that the needed closures of functional gaps to suit the TBL system are likely far off in time. Two key findings are:

- U.S. society will not come close to developing a TBL policy system as long as individual governing entities make policy and funding decisions focused mainly on *each* of the three bottom lines, with practically independent accountability. This goes for every step in the governing chains from federal, state, and local legislative committees all the way to the executive agencies at those levels. The research team did not find any political jurisdiction that has experience implementing the TBL concept.
- Transportation funding (and related policymaking) is significantly driven and limited by tax revenues on fuel consumption. For many reasons, this revenue has declined relative to overall transportation needs. Allocation of the funds remains structured and formulaic, leaving little flexibility to channel significant investments to TBL priorities that could be driven by high-level sustainability policy. TBL policy is neither explicit nor supported by institutional and funding arrangements today.

A TBL policy system will evolve slowly, because of the significant changes needed in institutional, governance, and funding mechanisms.

A TBL sustainable society is likely to evolve slowly from now, because of the very significant changes that will be needed—in institutional, governance, and funding mechanisms—for the TBL system to work.

Policy systems tend toward policy monopolies around issues—political alliances, institutional configurations, and conceptual understandings—that structure participation and policymaking over long periods of time (Baumgartner and Jones, 1993). The persistence of these systems generates patterns of political mobilization, citizens' ways of thinking about issues, and institutional structures that become ingrained and locked-in (i.e., difficult to change and resistant to outside influence). Paradigm shift usually comes from outside the policy system in the form of gradual, long-term change and growing stress (e.g., increasing energy prices, global climate change, growing public demands for environmental protection, changing economic conditions)—with the will of the public eventually driving the transformation.

The stressors build slowly. It can take decades for policy systems to tilt in a major way toward stress solutions. Energy price concerns and foreign petroleum dependence have been on the public agenda since the 1970s, and these stresses exert strong influence on all three of the sustainability bottom lines. Now technology development may stabilize or temporarily forestall these concerns going forward. Petroleum technology development and production investments such as shale oil extraction and synfuel manufacturing have been limited in the past by the ready availability and closely controlled pricing of benchmark crude oils, mostly from foreign sources. Because of increasing world demand, the foreign benchmark prices have risen to a level that makes increasing investment in new and alternative liquid fuel production capabilities financially feasible. In part because of the huge energy reserves in North America (shale oil and coal for synfuel), enough growth in liquid fuel supply can be expected to stabilize domestic (and world) fuel price growth and supply in the near-to-mid term.

When and if TBL policy systems do evolve, decision models for policy and funding will probably cross organizational and jurisdictional lines as they are currently known.

Responsibility for supporting, planning, and executing sustainable TBL will likely extend beyond the traditional jurisdictional and modal organizational boundaries of national, state, and local transportation agencies, because TBL policymaking and resource decisions will involve coordinated selection and execution of strategies by agencies and entities focused on all three bottom lines. Transportation will likely be called on to support and participate in policy (and possibly funding) decisions directly related to all three bottom lines as well. As authorities and TBL planning and management process requirements are gradually developed, the agency and interagency organizational structures will emerge based on specific needs for oversight, decisionmaking, execution, and compliance. Existing agency roles and functions would necessarily continue, but TBL management could take a matrix form, cutting across not only internal organization units but also across multiple external agencies. *Private- and public-sector entities could jointly occupy points in that management matrix.*

The final point above adds importance to the idea that agencies may consider a focus on making *public involvement and communications a much more positive force in transportation priority-setting and management.* Technological, social, legal, institutional, political, and economic changes have created an environment in which citizens, social groups, activists, and "super-empowered individuals" play strong roles in public policymaking. Whatever happens in the future, it is unlikely that this environment will change or diminish (Friedman, 2000). Most aspects of public policymaking and implementation are transparent and will likely become more open to citizen review and public comment, as well as more open to direct public engagement in decisionmaking. This does not necessarily mean that decisionmaking will be slowed down or impeded by public involvement processes. Public participation can be a vital, positive force. Citizens would need to be "co-producers" of TBL outcomes—that is, they would be directly engaged in the success of a policy, since significant behavioral change may be needed from citizens if a policy is to deliver its full benefits (Brandsen and Pestoff, 2006). Successful approaches are likely to be those that design policy around the assumptions that the public is involved in decisionmaking; the public is critical to successful implementation; and public trust must be built to enable the "right" decisions in periods of uncertainty.

These last principles are of critical importance in preparing for the shift to a TBL-based policy system. Effective public policy development requires a democratic foundation, but traditional participation models would need improvement and expansion to handle the increasingly complex challenges of TBL. In spite of positive strides in public participation today, there remains much room for expanded public roles—even under today's policy systems.

As (and if) a TBL policy system evolves in the future, agencies that have acted to build external decisionmaking models and lines of communication will be best prepared to transition to the more holistic transportation funding and management approach needed.

Transportation agencies are likely to always have similar roles and responsibilities, but the models to plan and execute these will need to change.

DOTs are most likely to continue to be responsible for design; construction; and safe, efficient operation of transportation systems. The point intended is that the *way* in which these responsibilities are executed in the future may continue to change.

This concept fits well for transportation. Under a TBL sustainability model, a transportation agency would retain full responsibility for transportation services and stewardship by collecting data, developing intelligence, and analyzing transportation needs and how they affect societal sustainability; formulating strategic policy; developing tools for implementation; building support for policy; developing the appropriate structures to implement policy; and ensuring responsiveness and accountability.

While remaining responsible and accountable for infrastructure and service delivery and operation, DOTs may not necessarily design, build, or operate the transportation infrastructure, in the way they do today. For example, DOTs could in the future assume broader responsibilities (possibly under a different name) for all infrastructure and operations that move energy, water, people, goods, communications, etc. Conversely, DOTs could eventually be subsumed under broader entities that manage commerce, or other functions related to all three of the TBL pillars.

The concept of ideal TBL balance and optimization is not prescriptive or idealized—TBL priorities will be driven by the public will, based on existing conditions and outlook.

There is no idealized formula or balance that is likely to achieve TBL under *all* scenarios in the future. The "acceptable" balance will be specific to the scenario, circumstances, and public demands that exist. Under any scenario, the challenge would be to preserve or improve conditions for the future, with practical strategies, resources, and technologies available. In each case, the will of the public—acting through representatives or commissioned authority—would likely drive the desired balance. Three points elaborate on this idea:

- TBL sustainability is a concept that seeks to achieve a particular (and sustainable) balance of social, economic, and environmental factors—to meet and preserve a standard of living quality *demanded by the public at a time and a place, region, or nation.*
- "One size" of TBL sustainability definitely does not fit all. The specific TBL balance demanded by the public is affected by existing conditions (under various future scenarios described later), including politics, culture, demographics, history, and probably many other factors.
- In each scenario case, the priorities for TBL sustainability will seek to preserve or improve all of the bottom lines, but where conditions permit, society may focus on improving the value of one or more of the bottom lines.

High-level, data-driven policy evaluation models are needed to support TBL consensus and policy system development.

There is a need for tools, which do not currently exist, to demonstrate the strong business case for TBL sustainability. Interviewees and the literature both conveyed the need to develop comprehensive business case assessment tools for sustainability that can clearly and credibly reveal—*and communicate*—ROI for TBL sustainability, expressed in monetary or monetary-equivalent terms, and take into account long-term intergenerational considerations.

The ROI tools needed have to address the full range of social, economic, and environmental elements of sustainability. Several such tools exist, or are under development [e.g., INVEST, PRISM™, HDR's sustainability ROI (SROI)], but such tools have not yet gained wide use or acceptance in the United States.

This report focuses on deeper research into key tools and methods to help agencies support and measure evolutionary sustainability initiatives today. The concentration is on rating and

assessment models, various decision-support tools (ROI-based) to assess multiple effects of transportation investments, and related cost-analysis tools.

User-funded and -financed transportation is a likely ingredient of effective transportation support of a sustainable society.

Today, transportation is funded primarily through fuel taxes that are collected based on road users' need to use fuel to move people and goods. The fuel taxes *are not directly* tied to "wear and tear" on the infrastructure, nor quality of service received, nor safety, nor efficiency—nor to the contribution of the transportation service to public goals for social, environmental, and economic well-being. Revenues have not met transportation investment needs in recent years because of vehicle fuel-efficiency improvements, changes in travel patterns, and other factors. Transportation performance and level of service do—to some extent—affect the long-established formulae for distribution of tax revenues to states, but funding levels do not respond very directly and quickly to high-level policymaking.

In a user-funded and -financed structure, it is possible that state and regional transportation users would be charged for system use in accord with the quality of service they received as well as for the value contributed by transportation to meeting overarching public needs, including economic and environmental health and social welfare. That same transportation user community (the public) would logically exercise more holistic and direct control of major allocation decisions. This control of priorities could overarch and direct the particular agencies responsible for executing chosen programs—whether they are transportation, environmental, social, or otherwise.

In this model, state and regional agencies would have increased ownership and decision-making leverage on collection and use of transportation revenues, subject to public policy in those states and regions. It can be concluded that if or when user-based charging accounts for more of the funding to support transportation services, transportation will be in a better position to support and respond to TBL sustainability strategies as they evolve in states and regions.

There are many complexities to the user-financed transportation model. For example, the highway system supports interstate commerce, as well as real and potential national security and defense needs. For these needs, it may always be appropriate to support basic capability and condition of the infrastructure to some extent through a national action.

Near-term strategies include TBL readiness monitoring, and building external dialogue and relationships on TBL decisionmaking.

Initiating and promoting multiagency and public dialogue is a very important component of agencies' anticipating and preparing for evolution of a TBL policy system.

Some agencies have invested time and resources in developing useful tools, rating systems, and measurement criteria for "sustainability" assessment and decisionmaking. The principal features of these initiatives can be applied *much more broadly* today. These tools and rating systems are developing, and application experience is building. If more widely accepted and adapted, they may exert significant influence on industry decisionmaking and standards in ways similar to how LEED is acting on the building industry today. The report includes considerable research material and treatment to cover key developing tools in the industry.

Looking forward to future TBL policy systems, the research outlines several approaches for agencies: (1) strategies to monitor evolution of the current policy system and to engage in dialogue on how cross-agency and cross-sector consensus might be reached on TBL decisions; (2) a questionnaire-based rating concept to assess specific agencies' readiness and functional

gaps (maturity) relative to a future TBL policy system end state; and (3) needed tools for TBL ROI analysis, total cost accounting (TCA), and life-cycle cost accounting (LCCA) that consider generational equity.

These tactics are well along in some agencies and represent tangible and relevant initiatives to pursue for many agencies. External dialogue on TBL consensus-building models may be the most valuable element of preparation. These still-developing tools and methods are useful to help move agencies in the direction of transportation-initiated actions that contribute to societal sustainability, but further decision modeling, computing, and data acquisition advances will help the tools become more useful and universal in the near-to-mid term. Chapters 7 and 8 of the report elaborate on tools and methods recommendations to support high-level functions, and provide deeper information on the most mature ROI and analysis tools.

Scenario Development

The policy system for sustainable TBL will represent large and gradual societal culture changes evolving over a long period. Because that system would evolve in future conditions, the research team used a scenario-planning approach to help frame the plausible conditions for transportation in a sustainable TBL society. The research team synthesized five plausible future scenarios, each with variations in some basic assumptions and scenario drivers. The team then evaluated these scenarios to determine key future challenges and opportunities for transportation. The five scenarios are briefly described as follows:

- **Crisis World**, the most "pessimistic" scenario the research team developed, is a world undergoing persistent, recurrent, multidimensional crises. Under this scenario, environmental crises and resource depletion are occurring much sooner and more quickly than currently anticipated, while the economy is trapped in an ongoing economic recession with slow growth.
- **Mega World** is one of two "as-expected" scenarios. The future is viewed as a general continuation of current trends. Economic and population growth are concentrated in growing megaregions; technology is anticipated to develop along all anticipated paths; and there is a slow adoption of new transportation funding mechanisms.
- **Suburban World** is also an "as-expected" scenario. The future is viewed as a general continuation of current trends. Technology is anticipated to develop along all anticipated paths and enables people to disperse to suburbs, small towns, and second-tier cities. There is slower adoption of new transportation funding mechanisms.
- **Wonder World** is one of two "positive" scenarios. In this scenario, there is better-than-currently-expected economic growth, and technology development is more rapid than currently anticipated. Environmental challenges remain manageable, and population grows rapidly. The dynamic economy, personal wealth, and technology lead to a more dispersed population.
- **Green World** is a mostly positive scenario. In this scenario, there is rapid economic growth, technology development, and population growth. There is also broad social and political consensus to strive to manage a "greener" sustainable society. As a result, there is substantial investment in green technologies and infrastructure, with substantial regulation and greater social and economic control.

Future Challenges and Opportunities for Agencies

Tables 3 and 4 list key expected challenges and opportunities that would plausibly arise under each of the scenarios developed. Please note that these are presented in the present tense, as from a future point of view.

Table 3. Challenges under various scenarios.

Scenario	Challenges
Crisis World	• Recurrent environmental crises that have dramatic negative impacts on transportation infrastructure; greater demands to maintain basic services. • Gradual, persistent, long-term economic decline and slow growth mean fewer resources available to achieve goals. • Reduced federal government spending and transfers to state and local government mean greater inequality between regions. • Lack of technological progress reduces the likelihood of technological solutions. • Difficulty maintaining all transportation facilities with constrained resources; need to prioritize crucial assets. • With assets that can be maintained and operated through user fees being privatized, agencies must decide whether to maintain low-demand bus routes, bridges, and roads. • Limited resources to enforce traffic rules and user safety. • Difficulty maintaining funding (i.e., worsening economic growth). • State government shrinks in response to declining revenues, resulting in fewer staff at transportation agencies. • Mishandled, poor, or missing information leads to bad decisions about funding priorities. • Fewer amenities (e.g., goods, healthcare, parks) available. • Entities' priorities differ, forcing the agency to make tradeoffs in deciding where to allocate limited funds. • Need for a process for decommissioning unsustainable infrastructure.
Mega World	• Gradual centralization to megaregions and megacities requires changing funding mechanisms and increasing spending on infrastructure. • Need to address social and economic equity impacts on the "left-behinds" outside megaregions (i.e., regions that are trapped in long-term decay and economic decline).
Suburban World	• Gradual decentralization from megaregions and megacities requires changing funding mechanisms. • Need to address social and economic equity impacts of regions trapped in long-term decline.
Wonder World	• Recurrent disruptive technologies cause dramatic change to society and the economy. • Increasing population growth and greater diversity of population (e.g., more diverse ethnic population and aging population). • Increasing economic and technological growth, leading to greater demand for mobility of goods and people. • Rapid technology innovations, leading to one region implementing a technology that quickly becomes outdated; technologies may not link across regions. • Some technologies may require new infrastructure (e.g., new right-of-way for smaller, lighter vehicles; "air train" rapid transit; multijurisdictional management systems). • Agency staff unable to keep up with technologies and needed changes. • New technologies require new standards and safety considerations. • Need for new transportation revenue sources as new sources of fuel and propulsion are used.
Green World	• Increasing population growth, greater diversity of population. • Demand that all sectors of society become substantially "greener." • Greater concentration of population in green urban areas results in need to address social and economic equity impacts on the "left-behinds" in less dense regions. • Major decrease in personal vehicle travel, requiring agencies to provide sufficient alternatives for intra- and intercity travel. • Moving away from carbon-based fuels requires new vehicles and new infrastructure.

Table 4. Opportunities under various scenarios.

Scenario	Opportunities
Crisis World	• Crisis allows for local and regional response to problems. • Region-specific crises create more need for regional, state, and local action and more flexibility. • Austerity forces transportation toward "low-level" sustainability, that is, reduce the size of the network and focus on key sustainable elements.
Mega World	• Gradual centralization to megaregions and megacities means cities and regions are more likely to have the resources to address problems.
Suburban World	• Gradual decentralization means cities would still have resources, but resources would be more dispersed along with populations and funding sources (infrastructure users).
Wonder World	• Resources are available to support expansion of sustainability-based transportation system. • Technology facilitates new planning and participation mechanisms, real-time performance management, and controlled and flexible resource allocation.
Green World	• Widespread support for sustainability. • Green technologies that will be developed will support sustainability.

Key Functional Gaps for Agencies

The research team compared the high-level functional characteristics of the current predominant transportation policy systems (Green Transportation, Level 2) to the functional characteristics needed for a TBL Sustainability (Level 4) policy system. The principal gaps to fill in those functional characteristics are as follows:

- Credible and widely applied performance measurement framework for TBL
- Application of LCCA, TCA, and sustainability accounting based on TBL
- Broad consensus on performance assessment processes to address TBL and the contribution of transportation to TBL
- Increased incorporation of TBL impact assessments in planning and programming
- Direct public- and private-sector engagement in needs development
- Market and business incentives for private industry to share and engage in TBL goal setting and decisionmaking
- Integration of sustainability tools in decisionmaking
- Established multimodal, multiagency, multisector, and multijurisdictional planning and decisionmaking to address evolving regional needs and consensus on TBL issues
- Multimodal, multiagency, multisector, and multijurisdictional programming with clear mandates and authorities (e.g., for megaregions) to better leverage resources

Addressing the Functional Gaps under the Scenarios

The research team then reviewed the functional gaps in the context of the scenarios and identified basic principles to prepare for change as the real future emerges. These principles are summarized briefly below and discussed in greater depth in the body of the report:

- **Adopting a precautionary (risk-based) approach to policymaking and decisionmaking.** A precautionary approach to decisionmaking means taking into account the level of risk, using existing knowledge, and accounting for uncertainties. The approach recognizes a social responsibility to minimize the community's exposure to harm as much as possible when detailed situational analysis and investigation have found a plausible risk arising from a decision or policy choice.

- **Choosing flexible or adaptive management options.** Flexible or adaptive management strategies are based on the insight that knowledge and understanding of social, economic, and environmental conditions is inevitably partial; limited; held in different forms (e.g., data, tacit knowledge and understanding, experiential information); and widely distributed among different individuals, groups, and organizations. Therefore, one single entity can never develop an all-encompassing vision of the world that correctly models all factors and elements likely to affect the outcome of a decision or public policy.
- **Using "no- or low-regrets" options.** No- or low-regrets options are built around the idea that "good" policy should bring near-term benefits as well as future benefits. Although this might reduce the potential for a policy to maximize benefits by "doubling down" on an attractive near-term policy option, caution may ultimately increase constituent value because it can help agencies deal with uncertainty.
- **Avoiding shift of burden.** This principle suggests that decisionmaking and policymaking should not resolve problems by shifting them to other areas, jurisdictions, modes, or other economic or social sectors. This principle is difficult to apply, but it is vitally important in a TBL policy system.
- **Dealing with complicated or "messy" futures, citizen cooperation, and government-as-enabler.** Social, environmental, and economic innovation can be messy and confusing. The future rarely comes as a unitary, easily understood event that everyone immediately comprehends and accepts. The future arrives at an uneven pace and is interpreted differently according to point of view, region affected, and many other factors.
- **Building internal adaptive capacity.** Agencies must build on capabilities needed to operate in unforeseen circumstances and volatile environments. For TBL to work in these environments, a broad framework for governance, decisionmaking, and strategic planning may be needed to connect and direct multiple bureaucratic organizations and private-sector leadership to mandate both focus and operations. Organizations need to develop more flexible internal structures, a capacity to recognize and accept change, and the ability to adjust traditional bureaucratic, hierarchical structures. In addition, organizations need to build more open, responsive, and resilient structures that focus on outcomes rather than process.
- **Making public participation a more positive force.** Technological, social, legal, institutional, political, and economic changes have created an environment where citizens, social groups, activists, and "super-empowered individuals" are a reality in public policymaking. Citizens are, in the terminology of current public administration literature, "co-producers," that is, they are critically involved in the success of a policy because substantial behavioral change is required from them if the policy is to deliver its full benefits (Brandsen and Pestoff, 2006). As such, transportation agencies need to adopt an approach to public participation with the assumption that the public is involved in decisionmaking and will be critical to successful policy implementation.

Strategies for Transportation Agencies to Consider

Selecting strategies to prepare for a future in which transportation can best support a sustainable TBL policy system depends on understanding the challenges and opportunities to be found in the envisioned TBL policy system and the gaps; that is, where do agencies need to go from here? The research team addressed the key issues for evolution to a new TBL policy system, followed by what agencies can reasonably do to assess, prepare for, and participate effectively in that evolution. However, it is clear that a viable TBL policy system will place great importance on close collaboration and strategic consensus among all levels of government—as well as private and institutional sectors.

Although the research shows that significant activity and momentum have been building around green transportation and context-sensitive development, there is no established experience with TBL sustainability to conclusively show that it is practicable. TBL sustainability is a concept whose practicality and results have to be measured over a period of years if not decades. Continuous situational assessment of society's perceptions and acceptance of the need for TBL sustainability—as well as the rate of adoption of measures and rating systems for TBL—will be useful for multiple agencies in decisionmaking on priorities, levels of commitment, and potential ROI for TBL initiatives.

General strategy development actions for agency consideration (in addition to tracking relevant legislation and rulemaking) include the following:

- Establish and/or participate in a national dialogue on evolution of a TBL policy system, including all levels of government and the private sector.
- Monitor and assess development and spread of sustainability rating systems and measures, particularly those sponsored by independent rating bodies.
- Monitor and assess measurement and certification standards development and adoption, particularly those that deal with two or more elements of the TBL.
- Monitor and assess deployment of sustainability tools and methods, particularly those adopted by several peer agencies, focusing on those involving two or more elements of the TBL.
- Conduct periodic discussions with stakeholders and constituents of the agency to take stock of the outlook for sustainable TBL; significant events, rulemaking, or trend changes in the factors monitored could trigger the timing of these discussions.

General-purpose tools and methods that agencies can adapt, develop, and use broadly to support a number of high-level agency functions include the following:

- Self-assessment tools to continuously gauge the "TBL maturity" and capability of the agency to be prepared for the next phase in sustainability policy system development; these will help prioritize near-term actions to improve or strengthen focus, if needed.
- Adoption and adaptation of appropriate sustainability-related ROI assessment tools that could support communication and decisionmaking for many agency functions.
- Surveys and scans to follow up on previous sustainability initiatives and decisions; these could confirm or calibrate logic and assumptions.

Transportation agencies today could implement these actions and tools at a relatively low expense. They are easily reversible, no- or low-regrets actions that would produce strategic information, including insight into future demands and benefits.

The following summaries are function-by-function strategies to prepare for and operate under a sustainable TBL policy system:

- **Development of Consensus on Needs:**
  - Reach consensus with stakeholders and partners on a definition of sustainability that is built on the TBL and accounts for the needs and priorities of the state and region.
  - Map agency goals to the proposed definition on sustainability.
  - Develop associated measurable objectives to track agencies' progress in addressing needs and achieving progress in meeting goals.
  - Develop performance measures tied to the proposed objectives and each focus area.
  - Develop mechanisms to communicate progress (using sustainability performance measurement tools) to the public and use these to develop a consensus.
- **Planning and Programming:**
  - Expand existing modeling and planning tools to account for multimodal options and impacts, as well as regional quality of life.

  - Coordinate data collection activities with engaged partners, including state and local agencies, as well as system operators and the private sector.
  - Connect the prioritization process and project development process to proposed TBL goals, measures, and objectives, such as ROI estimators, the Economic Assessment of Sustainability Policies of Transport (ESCOT) model (Schade, 2005), and the Assessment of Transportation Strategies (ASTRA) model (Schade et al., 2005).
- **Budgeting and Resource Allocation:**
  - Increase flexibility in budgeting, which may be needed to support risk sharing within and between agencies over multiple budget cycles. Agencies should consider long-term budget accounting and management and control of reserve accounts.
  - Consider the institution of TCA.
  - Consider integrating LCCA tools in the planning and budgeting processes.
- **Rulemaking and Regulation:**
  - Anticipate and prepare for new TBL-related rulemaking activities by, for example, initiating capture of data and measures likely to be required under new regulations.
  - Obtain a common understanding of the shared concerns, issues, and opportunities connected with TBL.
  - Determine overall ROI (the value proposition) for the participants in the collaborative effort (e.g., What is the benefit for each party and for all parties? What is the potential cost and risk of not acting?).
  - Monetize the impacts of potential regulatory requirements.
  - Connect impacts to jobs, commerce, and state/local revenues.
  - Develop high-level TBL-related planning and decisionmaking concepts.
  - Obtain TBL-related viewpoints, standards, and expectations.
  - Craft TBL-related measures.
  - Determine measures of success and rating.
  - Assess acceptance and adoption barriers and issues.
- **Service and Project Delivery:**
  - Adopt standards and approaches to identify sustainable options and ensure selected materials or systems purchased meet sustainable requirements (as defined in the development of goals, objectives, and associated performance measures).
  - Consider embedding sustainability/TBL-related ratings and standards into operational activities related to provision of transportation services, products, and infrastructure—including development, design, construction, operations, traffic management, maintenance, and preservation.
- **Education and Cultural Development:**
  - Consider the development of a sustainability code of ethics for the agency that focuses on supporting a sustainable society.
  - Develop and conduct training activities with internal staff on incorporating sustainability principles in transportation decisionmaking processes.
  - Set employee initiative and performance incentives associated with sustainability.
  - Set up and maintain an internal news forum and discussion on sustainable TBL.
  - Support the development of sustainability-related coursework in regional education institutions and encourage/support study by agency personnel.
- **Outreach and Communications (to Public and Stakeholders):**
  - Establish intra- and interagency coordination on TBL issues.
  - Conduct regular communication and information exchange activities with trade/professional groups, the private sector, and the public.
  - Keep outreach and communication activities ahead of the evolution of the transportation policy system.
  - Support overall outreach activities with relevant facts and figures as sustainable TBL initiatives progress.

Sustainability Tools and Methods—Key Directions for Development

A substantial body of knowledge and opinion has been growing in the last few years on sustainability performance measures and assessment/rating systems that address one or more of the three sustainability bottom lines addressed throughout this report.

At the level of transportation support for societal TBL and generational equity, models for the *contributions of transportation investments and returns on TBL* are easier concepts to visualize but challenging to develop and implement with current data and available algorithms. Key challenges include the following:

- Quantifying the full life-cycle cost of transportation programs (not necessarily projects)
- Total cost accounting at program levels
- Linking transportation performance and services to economic, environmental, and social bottom lines in simple and data-driven ways
- Valuating future (generational) transportation performance and TBL impact

Transportation agencies are adopting useful tools and methods today that will help agencies prepare for a sustainable future. These tools and methods include (1) sustainability rating systems and performance measures; (2) sustainability ROI estimators; and (3) LCCA, life-cycle assessment (LCA), and sustainability cost–benefit analyses of various kinds. These approaches focus on transportation planning and programming, and project delivery—mainly from within transportation agencies' mission and modal perspectives.

Key methods and tools evaluated include the following:

- Various approaches and methods in use for evaluating and rating sustainability characteristics under the planning and project delivery functions
- Models and issues for determining sustainability ROI
- LCCA, LCA, and cost–benefit analysis for sustainability
- Concept for Maturity (TBL) Assessment and Survey workbook

Possibly the most important need is a simple and easily communicated tool for determining sustainability ROI. There are several approaches that have been tried. None is sufficiently developed to serve the needed purpose. The principal development needs are for credible models relating the specific linkages between transportation investment and each of the three sustainability bottom lines.

Addressing TBL Sustainability—Now, and in the Not-Too-Distant Future

A true TBL policy system has not existed in the past or present, due in part to the lack of full consensus around implementable policy and investment decisions to drive TBL across jurisdictions, agencies, and multiple public and private sectors of society.

Nevertheless, progress is being made by agencies in the United States and around the world that have undertaken many sustainability initiatives and are advancing sustainability objectives and tools. In spite of this, there is not yet sufficient data or supportable models to link transportation investments to results at the three bottom lines, and to communicate the effects of TBL strategy alternatives simply and clearly to the public and to high-level decisionmakers.

However, there is good reason to believe that via dramatic technological advances over the next 10 years, the data and TBL modeling challenges seen today will greatly diminish, dramatically transforming the ability to make and communicate informed high-level TBL

decisions with confidence. Major technological and scientific advances are envisioned in four critical areas:

- Credibly supported and clearly understandable public information and measures to inform the public on TBL conditions and expectations—possibly including an authoritative quality-of-life index that incorporates the three bottom lines.
- "Big data"–driven TBL decision models to be used (and possibly integrated across multiple agencies and sectors) for effective management and execution of TBL sustainability policies by agencies and other actors.
- TBL-based policy evaluation models to support high-level consensus and policy system development across U.S. governance structures, based on data and measures that are sufficiently broad, yet reliable, to support effective policymaking and investments at a regional and national scale.

With the emergence of dramatically faster communication via the web and cloud, combined with improvements in artificial intelligence, processing power, and the availability of data, it will be much more likely that TBL decision-support challenges can be met in the next decade.

CHAPTER 1

Introduction

In 2009, the American Association of State Highway and Transportation Officials (AASHTO) allocated $7 million to conduct research on long-range strategic issues, both global and domestic, that will likely affect state DOTs. Seven research projects were initiated and addressed topics that included freight movements, sociodemographics, fuel supplies, climate change, technology adoption, system preservation, and sustainability as an organizing principle for state DOTs—all within a 30- to 50-year time frame. The projects had the following goals:

- Explore the impact of major trends affecting the future of U.S. transportation priorities and needs
- Provide guidance to state DOTs that will prepare them for possible futures so they can act, rather than react.

This research report is generated from one of these projects. The National Cooperative Highway Research Program (NCHRP) contracted with Booz Allen Hamilton (hereafter referred to as "the research team") to develop a framework for transportation agencies to use in identifying and understanding the future trends and external forces that will increasingly strain their ability to meet society's evolving demand for transportation services and to operate on a more sustainable basis.

This research was motivated by the increasing awareness that the transportation system must adapt to support a more sustainable society—specifically, transportation agencies face challenges in building consensus around balancing the short-term cost-effective delivery of transportation services and the long-term provision of the transportation needs of a sustainable society in a sustainable manner. Against this backdrop, the traditional functions of many transportation agencies are changing, and resiliency in the face of continuing and new demands by society may require agencies to fundamentally rethink the mission(s) and organizing principle(s) that drive them today. An analytical framework and supporting tools are needed to assist transportation agencies in evaluating their current and future capacity to support and contribute to a sustainable society, while delivering transportation solutions in a rapidly changing social, economic, and environmental (triple-bottom-line) context. This project helps respond to these needs.

1.1 Objective

The objective of this research was to provide a framework for transportation agencies' use in identifying and understanding the future trends and external forces that will increasingly put pressure on their ability to carry out their responsibilities to:

- Meet society's evolving demand for transportation services and
- Meet society's emerging need to operate on a more sustainable basis.

The framework will also provide a means for agencies to assess their future capacity to meet society's demands and provide or identify tools and approaches that agencies may use to assist them in making changes they deem appropriate and necessary to meet rapidly changing needs and conditions.

To accomplish these objectives, the research performed the following activities:

- Identified potential alternative future scenarios in which transportation agencies will be asked to achieve sustainability goals in providing for economic vitality, social well-being, and environmental integrity [the triple bottom line (TBL)] that reflect conditions 30 to 50 years in the future.
- Analyzed how transportation agencies' existing fiscal, legal, and institutional structure(s) and decisionmaking processes encourage or inhibit them from optimizing their contributions to a sustainable society.
- Examined the variety of roles and the nature of their related primary activities that transportation agencies may be expected to perform in the future.
- Explored linkages and expectations between transportation agencies and stakeholders and the need to form new alliances and partnerships with other transportation providers and system users.
- Provided or identified tools that individual agencies can use in designing their particular approach to adapting to the challenges and opportunities of the future and in describing, in broad terms, how sustainable transportation agencies might be organized.

Specifically, this project consisted of the following five phases:

- **Phase I.** Describe future scenarios and the difficulties, challenges, and opportunities that will likely require transportation agencies to make fundamental changes in how they deliver transportation services in a manner that contributes to a more sustainable society.
- **Phase II.** Assess the current and future ability of transportation agencies to support a sustainable society. Describe and assess the necessary evolution of linkages and relationships between transportation agencies and their partners and stakeholders. Identify barriers that may prevent transportation agencies from delivering transportation services in support of a sustainable society. Provide examples of transportation agencies that are well positioned to meet these future challenges or take advantage of future opportunities, focusing on practices or approaches that are transferrable to other agencies.
- **Phase III.** Determine inventory benefits achieved from business models, best practices, and lessons learned from other organizations, industries, or sectors (not limited to domestic transportation agencies) that have successfully adapted to rapidly changing external conditions.
- **Phase IV.** Describe plausible future roles and responsibilities of transportation agencies that deliver transportation services supporting a sustainable society. At a minimum, describe the organizational schemes, legal authorities, governance structures, and funding elements needed, as they relate to a broad vision of a transportation agency's mission.
- **Phase V.** Assess analytical tools and processes for agencies to use to track relevant trends and evaluate their current ability to meet future challenges or take advantage of pending opportunities in a manner that supports a sustainable society. Recommend tools and approaches that transportation agencies can use to implement the framework.

1.2 Scope and Limitations of the Current Research

Key limitations on the scope of this research report are as follows:

- This report is not intended to address the issue of sustainable transportation; it focuses on how transportation agencies can support a sustainable society.

- This report is not intended to propose specific policies, programs, or guidelines that can be followed to deliver a more sustainable society or sustainable transportation; it focuses on the factors affecting the functional capabilities of transportation agencies to support a sustainable society and how those capabilities can be addressed, given plausible future scenarios.
- This report provides recommended strategies and methods to help agencies anticipate evolution of a TBL sustainability policy system, and to act in the near term to prepare transportation agencies to best support a sustainable society in the future.
- This report focuses primarily on state transportation agencies; however, it does address how other regional, local, and federal agencies—as well as non-government entities—may be involved in future sustainability-related policy and decisionmaking.

One of the key limitations on scope referenced above is that this report is *not* intended to be an analysis of best policies for transportation agencies to follow to better support a sustainable society. There are a large number of potential policies that transportation agencies could undertake to increase societal sustainability. The applicability and effectiveness of these policies depend on numerous factors. Transportation agencies must select the mix of policies that best fit the challenges and opportunities they face. Furthermore, even though this project is future oriented, the research team does not know whether current policies deemed unrealistic (e.g., local or state carbon taxes) will become practical or appropriate in the future. As such, this project is "policy agnostic"—it does not recommend policies or take any positions. Instead, it focuses on how transportation agencies can change their organizational structures and functions to improve development, selection, and implementation of policies that are most applicable to the conditions they face.

Rather than being about what transportation agencies can do to support more sustainable transportation, this project is about what they can do to support a more sustainable society. As Figure 2 shows, this is a multifaceted problem. It includes not only the issue of how to create a more sustainable transportation system (presumably supporting a more sustainable society) but also the whole gamut of changes necessary to improve policy development, decisionmaking, and implementation. One of these challenges will be redefining some of the traditional decisionmaking roles of the stakeholders involved in long-range transportation planning in order to include representation of other agencies or social groups affected by transportation decisions. Building consensus and sharing both resources and risks among these stakeholder groups may prove to be two of the most critical aspects of moving toward a sustainable society.

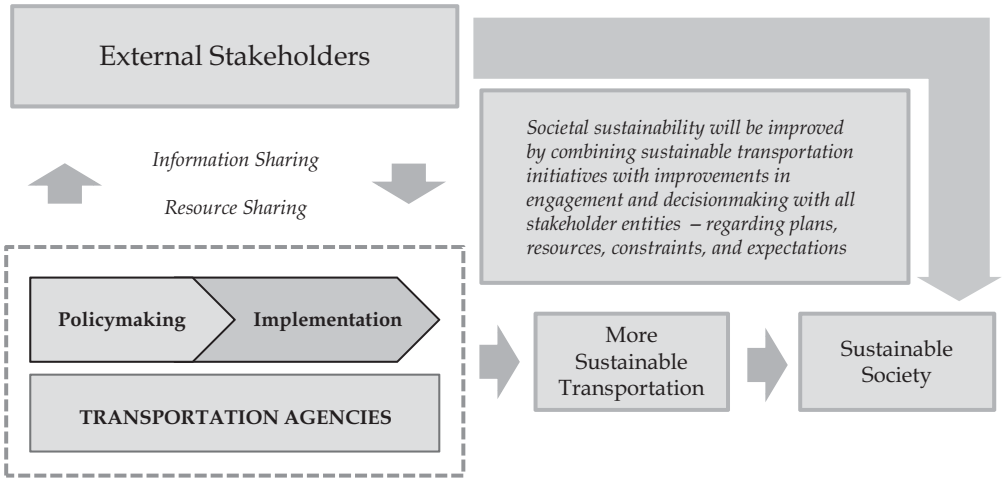


Figure 2. The relationship of transportation agencies and external stakeholders in support of a sustainable society.

Finally, while this project primarily focuses on state transportation agencies, it also addresses the broader institutional and political environments in which they operate (e.g., the relationship between state executives, legislatures, interest groups, business interests) and other types of transportation agencies, such as regional transportation agencies, metropolitan planning organizations (MPOs), localities, transit authorities, and system operators. Thus, while these findings are of greatest interest to states, they may be useful to other transportation agencies facing similar challenges and opportunities.

1.3 Defining "Sustainability"

Critical to framing this research and understanding its conclusions is the concept and definition of sustainability. The Brundtland Commission, formally the World Commission on Environment and Development (WCED), supplied the classic definition of sustainability. The commission was created to address growing concern "about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development" (WCED, 1987). In establishing the commission, the United Nations General Assembly recognized that environmental problems were global in nature and determined that it was in the common interest of all nations to establish policies for sustainable development. The final report of the Brundtland Commission, *Our Common Future*, defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). This definition, however, has been interpreted widely.

NCHRP Report 708: A Guidebook for Sustainability Performance Measurement for Transportation Agencies developed guidance for state DOTs and other transportation agencies to understand and apply concepts of sustainability and to begin to assess and measure their performance in terms of sustainability goals. *NCHRP Report 708* presents the following conclusions:

- There is no agreement on the terms "sustainability" and "sustainable development." All definitions will be contested and are open to question.
- Typically, sustainability is considered to be a combination of three dimensions: economic, social, and environmental (the TBL).
- The issues of future needs (i.e., intergenerational equity) and governance are also relevant.
- Growth in well-being, rather than pure economic growth, is desirable and is related to the concepts of a strong versus weak approach to sustainability.[3]
- There is a need to better understand the implications and tradeoffs if all aspects of sustainability are treated as fully tradable concerns from the economic paradigm.

This project adopted the following definitions of sustainability, sustainable development, and sustainable transportation:

- **Sustainability**—Sustainability encompasses a holistic consideration of economic, social, and environmental progress with a long-term perspective, in both a present (intragenerational) and future (intergenerational) context. The principle of equity is viewed as reinforcing each of the sustainability dimensions (Zietsman et al., 2011).
- **Sustainable development**—Sustainable development can be viewed as a process of working toward achievement of sustainability, with a particular focus on human needs. Traditionally, it is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

[3] TBL does *not* refer to what is known as "strong" sustainability, which treats the environment as fixed capital and in which tradeoff choices are made at the expense of the economy and (sometimes) social values. Strong sustainability fits within today's policy system, wherein such tradeoffs are frequently made. Rather, TBL refers to the "weak" sustainability concept, in which all three bottom lines are traded off, balanced, and optimized.

- **Sustainable transportation**—"A sustainable transport system [is] defined as one that (1) allows the basic access and development needs of individuals, companies, and society to be met safely and in a manner consistent with human and ecosystem health and promotes equity within and between successive generations; (2) is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development; and (3) limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses nonrenewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise" (European Union Council of Ministers for Transport and Telecommunications, 2001).

A fuller expression of sustainability has emerged with the development of TBL (referred to as "people, planet, profit" or "the three pillars"; Bader, 2008). TBL is intended to capture the full range of goals that a sustainable organization should consider—specifically, economic, environmental, and social goals. The concept of TBL goes back to 1994, when John Elkington argued that companies should prepare three bottom lines: (1) the traditional account of profit and loss; (2) a "people account" (i.e., a measure of an organization's social responsibility); and (3) a "planet" account (i.e., a measure of environmental responsibility) (The Economist, 2009).

In the United States, the concept of TBL has appeared at the state level as a greater commitment to developing business performance measures and tracking. For example, in 1989, the Oregon state legislature created the Oregon Progress Board (OPB) as a state agency to track quantitative indicators for the state of Oregon. The OPB was charged further with keeping the public up to date on the implementation of the state's strategic plan for sustainable development. The plan had three key goals: (1) quality jobs for all Oregonians; (2) safe, caring, and engaged communities; and (3) healthy, sustainable surroundings. In 2000, an executive order from Governor John Kitzhaber established a set of sustainability-based goals:

- Increase the economic viability of all Oregon communities and citizens.
- Increase the efficiency with which energy, water, material resources, and land are used.
- Reduce releases to air, water, and land of substances harmful to human health and the environment.
- Reduce adverse impacts on natural habitats and species.

In response, the OPB created a set of sustainability indicators grouped into seven principal categories: economy, education, civic engagement, social support, public safety, community development, and environment (Schlossberg and Zimmerman, 2003). Table 5 lists some of these indicators. As can be seen, efforts to track TBL performance on a macro-statewide scale can include

Table 5. Illustrative sample of TBL indicators—State of Oregon.

Environment	Community	Economy
Stream water quality	Child abuse or neglect	Drinking water
Native plant species	Teen pregnancy	Research and development
Forest land	Homelessness	Eighth-grade skill levels
Air quality	Health insurance coverage	New companies
Agricultural land	Overall crime	College completion
Marine species at risk	Teen alcohol abuse	Living wage
Native fish and wildlife	Juvenile arrests	Poverty
Carbon dioxide emissions	Commuting	Per-capita income
State park acreage	Vehicle miles traveled	Economic diversification
Municipal waste disposal	Volunteerism	High school dropout rate
Nuisance species		Employment dispersion
		Affordable housing
		Timber harvest
		Income disparity

a large number of diverse indicators. Integrating all of these indicators and communicating a credible overall scorecard presents very complex and difficult weighting and normalization challenges. Developing criteria and reliable measures of change or quality for each indicator is an additional challenge.

In the transportation community, the research indicated broad agreement for the concept of TBL. As discussed below, many state DOTs, MPOs, local governments, and other agencies involved in transportation are applying the concept of TBL to their decisionmaking and are actively developing policy, guidance, or performance-based indicators (Schiller et al., 2010). In fact, compliance with the TBL is seen generally as the principal way in which sustainability has been incorporated into the conduct of government business at the state level. Other concepts associated with sustainability, including intergenerational equity, the precautionary principle, and integrated decisionmaking, have received substantially less attention (Dembach, 2002).

Internationally, several countries have progressed significantly in implementing TBL accounting and reporting. For example, Australia's Federal Department of Family and Community Services began to produce an annual TBL report as early as 2002, and the government of the state of Western Australia has developed a detailed sustainability plan with explicit TBL targets (Barrett, 2004; Government of Western Australia, 2003). Similarly, in the United Kingdom, many government agencies and semipublic organizations have developed detailed TBL scorecards and performance-tracking measures. For example, the U.K.'s National Health Service (NHS), the largest employer in Western Europe, has developed detailed TBL sustainability guidance for its operating units, including processes for conducting sustainability assessments. NHS developed TBL performance indicators and scorecards and recommended actions needed to support achieving TBL goals (Lockie and Bourke, 2009).

Based on the research, the following working assumptions are used to help clarify the sustainability concept for the purpose of this report:

- **TBL is fundamental to the emergence of sustainability in the public and private sectors.** Pursuit of TBL has become fundamental to the concept of sustainability. Both public- and private-sector organizations have developed their sustainability programs around the concept of the TBL.
- **Sustainability focuses on the long term, rather than the short term.** The key requirement of sustainability is to accommodate both present and future development needs.
- **Sustainability is an integrated rather than a stand-alone concept.** Sustainability is not exclusive to any one policy area. Specifically, given the integrated nature of transportation with the rest of human activity, it is difficult to view the transportation system in isolation. Sustainable transportation requires that the team consider a broad definition of sustainability that considers how transportation affects overall social sustainability, and how other policy areas need to be coordinated to achieve sustainability.
- **Sustainability is multidimensional.** It is not simply about "greening." Sustainability has economic, social, and environmental dimensions—the TBL. These dimensions do not represent clearly distinct compartments; rather, they provide ways to systematically view the interlinked character of societal development as it draws on environmental, economic, and social resources and mechanisms. Development along the TBL dimensions does not take place in a governance vacuum; it presupposes institutional arrangements and reforms.

1.4 Achieving "Strong" vs. "Weak" Societal Sustainability

Turner (1992) refers to two contrasting views on managing and achieving societal sustainability. Each has very distinct implications for results and for policies governing strategic planning, tradeoffs, and regulation. The two views highlight a very important contrast between many of the

sustainability initiatives being pursued today versus a vision of a future TBL societal sustainability policy system.

The "strong" and "weak" sustainability definitions depend fundamentally on the treatment of social, environmental, and economic stores of capital value to the public. General definitions of the three stores of capital are environmental capital is the value of the quality and health of the environment; social capital is the value of social conditions and the networks of relationships that support social needs; and economic capital is the value of economic growth to support and improve the health and welfare of a society. Presumably the total "value" of all three capital stores should be maximized for best overall societal well-being—provided the values of the three stores are maintained in an acceptable balance or proportion to each other, as determined by local, regional, and/or national public will.

In "strong sustainability," environmental capital is treated as essentially nonrenewable. It must be either maintained or improved (in some views, social capital is treated similarly). So, in the strong form of societal sustainability, economic capital is usually the primary store to be drawn from when needed to meet environmental and social goals and to keep the three aspects of sustainability in balance. In a vigorous economy, there is opportunity to both balance and improve the value of all three stores. In a sluggish or recessional economy, "strong sustainability" principles might maintain social and environmental capital but could disproportionately exacerbate economic challenges.

In "weak sustainability," all three stores of capital are considered flexible and renewable (or replaceable through, for example, alternative energy supply, better environmental remediation technology, or improved recovery of resources) to some extent to allow for practical tradeoffs to balance or improve all three capital stores. The weak sustainability principle could, of course, work best with a strong economy and without severe stress on the environment. In a very weak economy with major environmental stresses present, all three capital stores would likely decline proportionally in "value."

The research team notes that most, if not all, of the initiatives today are of practical and regulatory necessity and are characteristic of "strong" sustainability principles. It is not intended for the research to be critical of strong sustainability—but rather to suggest that, in the future, TBL ("weak") sustainability may be a viable generational objective with good prospects for meeting society's needs, and for *improving long-term societal conditions along all three bottom lines.*

1.5 Roadmap for the Research and Report

Evolution of the sustainability policy system (organizing principle) and the high-level functional framework for transportation are explained in Chapter 2. Scenario development is covered in Chapters 3 and 4. The functional challenges and gaps are addressed in Chapters 5 and 6. Chapters 7, 8, and 9 address near-term strategies, tools, and methods for consideration by transportation agencies to address gaps that can be closed or initiatives to prepare for gaps as a TBL policy system evolves.

Appendix A contains a detailed description of the assumptions—or drivers—used to create each future scenario. Appendix B provides data on state, local, and federal spending and other data used to create the scenarios. Appendix C presents the energy consumption forecasts, from the U.S. Department of Energy's National Energy Modeling System, that were used in constructing each scenario. Appendix D characterizes the current literature and summarizes the results of practitioner interviews. Appendix E identifies the affiliations of practitioners interviewed. Appendix F contains the TBL Maturity Assessment Tool. An acronym list is included after the Table of Contents.

CHAPTER 2

Policy Systems and Transportation Functions

2.1 The Systems Analysis Model

This section includes a gap analysis and identifies the challenges and opportunities that transportation agencies might face under different future scenarios. A basic systems analysis model organizes and shapes this analysis. This model assumes that all public policy is made in discrete, semi-autonomous systems. These systems are connected to the wider political system, but are largely autonomous and dominated by a set of interests, political and institutional actors, and policy outputs unique to that system. Thus, while transportation agencies are part of the larger governmental system, they interact with a particular set of political and institutional actors (e.g., legislative transportation committees, transportation interest groups, state transportation commissions, U.S. DOT), have a particular set of institutional and organization relationships (e.g., DOTs, MPOs, local highway departments), and have distinct responsibilities and operating requirements (e.g., build, operate, and maintain state highway systems; regional transportation planning). Furthermore, the political and institutional system in which transportation agencies operate is autonomous in the sense that the work of transportation service provision and regulation is left to them. Other agencies and actors may become involved in transportation, but the day-to-day business of transportation service provision is left to the transportation policy system. The making and implementation of transportation policy can be analyzed separately from the overall policymaking system.

Figure 3 shows the basic systems model (Easton, 1965). David Easton first described this model in the mid-1960s. Since that time, it has formed the basis for comparative public policy and public administration analysis (Rissmiller, 2010).

The basic systems model assumes that a policy system can be identified as a series of relationships, organizations, institutions, activities, or interactions between actors that relate more or less directly to a particular policy domain (e.g., transportation, environment, health). A policy system is a conceptual entity that is generally accepted by most individuals within a society as having the authority to measure demand and allocate public goods[4] for a specific geographically defined community (e.g., city, county, state, region, or nation). Thus, a state transportation policy system is the set of organizations, people, processes, and institutions that have the legitimate authority to take demands for transportation goods (e.g., roads, railways, regulations, safety programs) and translate them into specific public goods and services.

The policy system is separate from its external environment, which includes all elements that make up the physical, social, economic, legal/regulatory, and institutional world in which the

[4] "Public goods and services" means the goods and services a government provides its citizens through the public sector, through financing private provision of services, or through policies that encourage individuals, the private sector, and other groups to provide those goods and services. Even when these things are not provided or financed publicly, they may be subject to regulation.

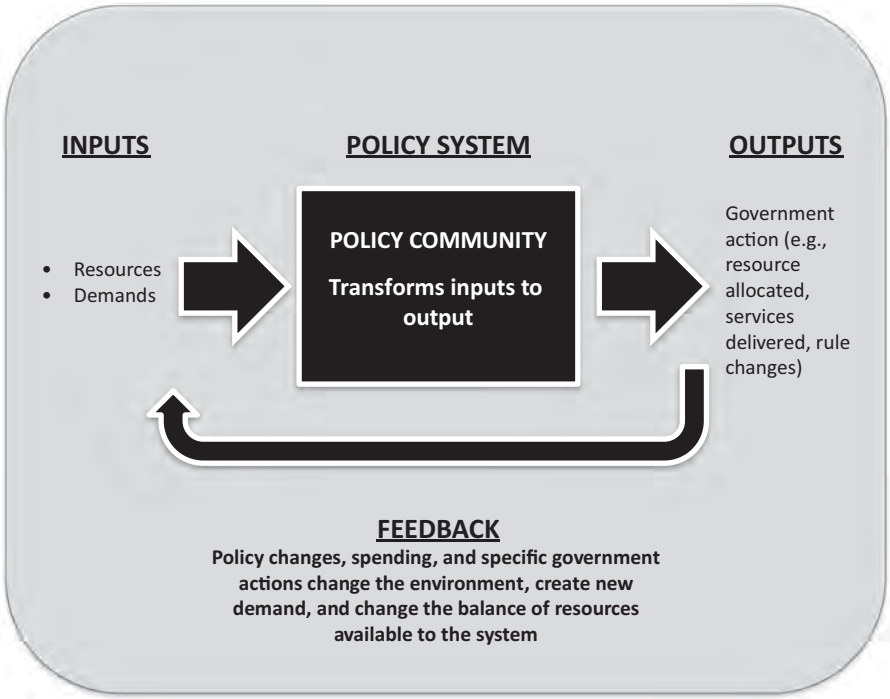


Figure 3. The basic systems model.

policy system operates. The environment (via an input–output exchange) affects the policy system, and the actions of a policy system affect the environment.

The policy system processes three main elements:

- **Inputs.** Changes in the social or physical environment surrounding a policy system produce demands and supports for action or the status quo directed as inputs toward the political system, through political behavior.
- **Outputs.** Demands and their supporting groups stimulate competition within a policy system, which results in decisions or outputs directed to changing or maintaining some aspect of the surrounding social or physical environment. After a decision or output is made (e.g., a specific policy), it interacts with its environment. If it produces change in the environment, there are outcomes.
- **Feedback.** When a new policy interacts with its environment, outcomes may generate new demands or supports and groups in support of or against the policy (feedback) or a new policy on some related matter. Feedback in turn creates new inputs, which create a new cycle of action.

2.1.1 Inputs

Inputs to a policy system should be understood broadly. Inputs may include but are not limited to the following:

- **Resources.** For example, money, time, available raw materials, energy, labor, grants of authority (i.e., recognition by another entity within the political system that a particular policy system has the right to influence the distribution of public goods within a particular domain).
- **Demands.** This involves legislative actions (e.g., laws, budget allocation); executive decisions (e.g., executive orders or direction from top elected officials, such as governors, mayors, or

transportation commissioners); interest group lobbying; lawsuits and court orders; information collected from citizen outreach; business or citizen requests; or any other method by which demand, requests, or other claims on the direction of public goods can be made. Note: Demand may be positive (i.e., do something), negative (i.e., do not do something), or sustaining (i.e., continue to do something/do not change).

Typically, demands emerge through a three-stage process (Ostrom and Ostrom, 1977):

- **Awareness.** All individuals, groups, communities, businesses, and social groups experience a degree of stress between their preferred state and the current state of the environment in which they live. When this stress grows to a certain point, they may attempt to influence the government to reduce this stress. Initially, these demands are rudimentary, but through collaboration and exchanging ideas, they gradually form into coherent demands.
- **Articulation.** This second stage of the process is known as *issue articulation*, in which various social groups and interested parties express their needs for policy outputs. Issue articulation may range from personal contact with government officials (e.g., lobbying, participation in public planning forums, peaceful protest, phone calls and letters to policy makers) to the development of interest groups (e.g., trade unions, professional associations, single-issue campaign groups).
- **Aggregation.** Issue articulation leads to interest aggregation, where groups and individuals team up to make specific policy demands. For example, a number of local community interest groups, businesses, and environmental groups join together to form a program that demands that a city transportation agency reduce congestion by developing a public transit system. In this example, the presence of congestion would initially give rise to a degree of stress between many groups' and individuals' perceived ideal and the actual state of the local environment (e.g., perceived reduced business opportunities, long commutes, increased environmental contamination). Gradually, these groups and individuals would articulate their issues and then aggregate them to develop a coherent set of demands on the government.

Clearly, issue articulation is not a unitary process. Outside of the government, a variety of formal and informal mechanisms exist to formulate demands. Public-sector agencies can play a positive role in this process to help various groups and individuals. For example, the development of MPOs and public participation mechanisms in the continuing, cooperative, and comprehensive (3C) planning process instituted by the National Environmental Policy Act (NEPA) provide the government with a positive outreach tool that brings stakeholders and interest groups into a planning process. As transportation agencies improve their support of the articulation and aggregation of public demands, they become better able to support a sustainable society.

Another issue to consider is that old demands are rarely replaced by new demands. New demands are added to old demands and the burden on public policy systems increases. For example, the 20th century saw a constant expansion of the demands placed on transportation systems. From the Good Roads movement of the late 19th and early 20th centuries to the current transportation system, mobility, economic competitiveness, equity, environmental protection, public participation, and safety remain paramount, but new demands are added constantly. Sustainability will be added to the existing set of demands and will have to manage tradeoffs between the old and the new.

The key function of the overall policy system is to transform inputs into outputs. That is, resources and demands allocated to the policy system are translated into outputs that change the transportation environment. In recent years, the concept of the policy system has moved from the more mechanist vision of early public policy theorists toward the idea of policy communities or policy networks (Skogstad, 2005). Policy communities are networks with relatively few actors or participants collaborating continuously on a set of policy issues. They share a general agreement over the scope, goals, and general institutional processes leading to policy output. In addition, they share a belief system, accept formal and informal codes of conduct, and follow established patterns of behavior. Policy communities are also involved in the delivery and development of policy.

2.1.2 Policy Community

The concept of policy communities is well accepted in public policy literature (Skogstad, 2005). It grew out of the recognition that, as policymaking had become more complex, specialized, and fragmented, the government realized it needed the resources and cooperation of non-state actors. Simply put, democratic, representative governments cannot function without the consent and involvement of its citizens. Their input into policy formation, and hopefully resulting support, is crucial. Focusing on formal and macro-level decisionmaking bodies—like state legislatures, governors, or mayors—ignores the realities of the policy process.

Transportation policy issues usually involve a relatively small number of actors or participants who are drawn together because they have a legal requirement or authority to participate (e.g., state DOT staff, MPOs), an interest in the policy outcome (e.g., business interests, environmental groups), or a technical interest in the issue (e.g., professional societies, academics). Only rarely do transportation issues reach the point where a large number of people and interests become involved (e.g., the development of a major new highway interchange or bridge, the addition of capacity on existing highways, the building of a new transit system, the expansion of a metro system, the adoption of congestion-pricing strategies, proposing new revenue sources to fund transportation projects or programs).

In this approach, there are three critical characteristics of any policy community:

- **Policy paradigms.** These are a set of beliefs or basic principles that are used to organize any system and a series of preferences that suggest how policy should be delivered.
- **Actors.** These are specific individuals, organizations, interest groups, or other entities that interact with each other to develop and implement different policy.
- **Functions.** Every policy community has a set of functions (e.g., develop and deliver transportation services) and an internal subset of functions that each actor carries out to achieve the overall community's assigned function. These functions may include needs assessment, budgeting, planning and programming, service delivery, and education and outreach.

Policy paradigms are deep-seated psychological and cultural structures that define the scope and extent of a policy community. They define what should be the scope and overall goal of the community (i.e., organizing principles, the actors that can or should be involved, and the relationship between those actors) (Wilson, 2000).

The paradigm consists of three components: (1) a deep, core set of beliefs or organizing principles; (2) a set of policy preferences; and (3) a set of instrumental preferences. Table 6 shows the structure a policy paradigm.

Deep core beliefs or organizing principles express foundational beliefs about society, human values, and other related issues. These beliefs color all understandings and are unlikely to change. For example, the transportation policy goal of mobility emerges from a range of core beliefs associated with individual freedom, including free movement.

A second set of beliefs, or preferences, is constructed on top of the core beliefs. These policy preferences address fundamental positions on how best to achieve deep core beliefs. For example, an individual may believe that the free market is more effective in achieving social goals than the government. These beliefs tend to apply to specific policy areas but are not held across all policy areas consistently.

Finally, instrumental preferences concern instrumental decisions and methods to achieve goals. For example, two individuals may differ substantially on the role of the federal government in environmental policy, but agree that the *Federal Register* should contain the information about decisions made on environmental policy.

Table 6. Structure of policy paradigm.

	Organizing Principles or Deep Core Beliefs	Policy Preferences	Instrumental Preferences
Defining Characteristics	Fundamental normative and ontological axioms (e.g., the Earth is here for humans to use, we are all part of nature and must live in balance)	Fundamental policy positions concerning the basic strategies to achieve normative and ontological axioms (e.g., the market is always best, planning and management are the best way to achieve social goals)	Instrumental decisions needed to implement a core belief
Scope	Basic personnel philosophy—influences everything	Applies to all policy areas	Specific to particular issues—especially technical issues
Susceptibility to Change	Very difficult to change—requires a conversion experience	Difficult to change but can change if experience reveals fundamental anomalies or repeated difficult-to-explain phenomena	Moderately easy—this is the area where most policy discussions and debates occur

The policy paradigm determines the actors who should be involved in policymaking and implementation. For this report, actors are divided into three major groups (Kraft and Furlong, 2012):

- **Group 1.** This group includes government-sector actors (e.g., governors, state legislators, state transportation officials, mayors, members of MPOs).
- **Group 2.** This group includes private-sector economic actors (e.g., businesses, banks, farms, small businesses, major local economic interests, system operators [freight railroads, shippers, receivers]).
- **Group 3.** This group includes civic-sector actors (e.g., environmental interest groups, transportation use associations, community groups, unions, academics, professional bodies).

Sample Policy Paradigm: Transportation Policy 1950–1970

- Based originally on need to support national defense
- Financed through a combination of state and local taxes and fees and federal grants funded by national motor fuel taxes
- Largely ignored environmental and social equity impacts that were associated with transportation capacity building
- Did not consider how decisions promoted long-distance urban–suburban travel and facilitated low-density sprawl developments
- Allowed pricing distortions that promoted motoring at the expense of walking, biking, and public transportation
- Took a "build-our-way-out-of-congestion" approach, rather than attempting to manage demand
- Favored one mode (roads and motor vehicles) and one technology (private automobiles), rather than a balanced multimodal view
- Adhered to technocratic decisionmaking and attempts to minimize public participation
- Defined safety narrowly, often as motorist safety only

(Schiller et al., 2010)

The distinction between Group 2 and Group 3 is somewhat arbitrary. Some firms and businesses can be organized into civic-sector groups to attempt to lobby government (e.g., business involved in chambers of commerce). Some actors are sovereigns (Sabatier and Jenkins-Smith, 1993). *Sovereigns* are actors that have the final authority to make a policy decision for different levels. These individuals might be governors, heads of DOTs, or mayors. Actors may be described in terms of their role and responsibility in the policy system, their function or purpose, their power and authority (e.g., ability to allocate resources, ability to direct other actors or participate in decisionmaking), the rules that apply to them, and the process they are required to follow to perform certain functions.

Considering all these factors, a number of different types of actors that are present in state transportation policy communities can be identified. Table 7 shows a generic overview of these actors.

Based on this analysis, several key functions that policy community actors perform in the transportation arena are shown in Table 8.

2.1.3 Outputs and Feedback

A policy system produces various outputs. These include a wide variety of public goods, including direct allocation of money to specific groups, spending on investments or operations, or regulations and guidance. Note that one of the decisions of the policy system may be *not* to do

Table 7. Sample generic actors in state transportation policy communities.

Actors	Govt. Sector	Private Sector	Civic Sector
State legislature (individual legislators, legislative committees)	●		
Governors	●		
Heads of DOTs	●		
Transportation commissions	●		
Federal departments (e.g., DOT, EPA)	●		
State DOTs	●		
MPOs	●		
Local governments	●		
Other state government agencies (e.g., state environmental protection agencies)	●		
Other modal authorities (e.g., airports, ports, passenger rail)	●	●	
System operators (e.g., freight railroads, toll operators)	●	●	
State and local economic interests (e.g., large businesses, small businesses)		●	
Developers (i.e., businesses and firms involved in developing property for high-value use)		●	
Transportation providers (i.e., businesses and firms involved in the provision of transportation services for both people and goods)	●	●	
Community and civic groups (e.g., community booster groups, chambers of commerce)		●	●
Environmental nonprofit groups			●
Professional organizations and research organizations (e.g., National Association of Fleet Operators)	●	●	●
Single-issue transportation groups (e.g., CorridorWatch.org—concerned Texans and public officials opposed to the Trans-Texas Corridor)			●
Transportation user and advocacy groups (e.g., National Alliance of Public Transportation Advocates, American Public Transportation Association, Bay Area Bicycle Coalition, Tri-State Transportation Campaign)			●

Table 8. Transportation policy system functions.

Functions	Functional Definitions
Consensus on Needs and Goals	Processes by which transportation policy systems identify needs, gaps, and requirements; build consensus around a prioritized ranking of potential needs; and develop acceptable goals and priorities for transportation.
Planning and Programming	Processes by which transportation plans are created to carry out the goals developed in the consensus-building, needs-assessment, and goals-setting processes; plans are then turned into processes, which are created and authorized to carry out the goals set in the consensus-building, needs-assessment, project-prioritization, and goals- and objectives-setting processes.
Budgeting and Resource Allocation	Processes by which transportation policy systems determine how to collect and distribute resources among different projects and programs (includes budgeting and allocation).
Regulation and Rulemaking	Processes by which rules, regulations, standards, and guidelines are established for compliance with legislated mandates and laws.
Service and Product Delivery	Processes by which transportation policy systems deliver transportation goods and services to the public and ensure that the level and quality of services meet goals and established standards.
Compliance and Dispute Resolution	Processes by which the transportation community sees that the intent of legislation, standards, and regulations is complied with—and processes by which disagreements over interpretations or tradeoffs can be resolved.
Education, Training, and Culture Change	Processes by which the transportation community is educated to understand and embrace evolving organizing principles and to adopt (and invest in) behavioral norms* associated with those principles.
Outreach and Communications	Processes by which information on needs, strategies, expectations, and results are shared broadly by stakeholders in the public- and private-sector transportation community—critical processes to support consensus-building, policymaking, planning, and decisionmaking.

*Some examples of adopted behavioral norms include energy conservation, recycling, seat-belt habit, aversion to littering, acceptance of user charging, pursuit of diversity and social equity, and self-regulation.

something. For example, the decision not to make a major investment in public transit may be as important as the decision to invest in public transit and may have major implications regarding who is able to use government resources.

A policy system's decisions have direct and indirect impacts on the environment in which it operates. These, in turn, affect the demands made on the policy system and the resources available for future policy actions. For example, the emergence of cars after World War II as the dominant form of personal transportation encouraged suburban sprawl. This, in turn, changed the resource balance between cities and suburbs and placed new demands on local transportation agencies.

2.2 Policy Change

The issue of how policies change is very relevant to this project. Specifically, how transportation policy systems can be induced to change and the processes for framing new policies are important to the understanding of how a more sustainable society could be achieved under different scenarios. This section presents research on models that explain policy change and the dynamics of policy framing.

Historically, the literature on policy change tends to emphasize the limitation on decision-making and implementation and the resistance of the American policymaking system to change (Downs, 1967; Wilson, 1989; Moe, 1989). This literature stresses the complex, multifaceted nature of American society and the existence of numerous counterbalancing interests that make

change extremely difficult to achieve in an open, highly decentralized system such as that found in the U.S. Given such a system, it is extremely difficult to persuade sufficient people and interests to accept radical, potentially high-risk change. This leads to incremental decisionmaking where policy change is slow and focuses on low-risk innovations. Change only occurs when there is a clear consensus on the need for change and how that change should be achieved. Even then policy change tends to be slow and incremental.

A more recent view of policy change is the path-dependent model (Pierson, 1993, 2000). This model attempts to explain continuity and resistance to change as part of the natural consequence of bounded rationality and a pragmatic adjustment to existing conditions. Under this model, policy change is limited by past policies and decisions and the existence of institutions, rules, and laws that limit the extent of policy change. This leads to "lock-in" effects, where current policy paradigms come to dominate the public's view of what is possible and can be changed. For example, in the area of transportation policy, decisions made decades ago on the transportation infrastructure continue to constrain and limit policy choice.

However, while the incremental model and the path-dependent model both explain why change is slow or does not occur when faced with crisis, they both lack an explanation of how change occurs. The punctuated equilibrium model (Baumgartner and Jones, 1993) seeks to fill this gap. Under this model, policymaking is characterized by long periods of stability with minor, incremental change (i.e., a policy equilibrium exists), followed by periods of instability (created by endogenous or exogenous change) and major policy change. During these periods of instability, a major challenge to the current consensus emerges that destroys current alliances between important groups, undermines long-held assumptions or beliefs, and renders existing approaches irrelevant. If the challenge is successfully addressed, the system reaches a new equilibrium and policymaking returns to its incremental development.

In this model, policies change when they "become stressed, alternative policy paradigms arise, legitimacy crises occur, and shifts in power become evident" (Wilson, 2000). Stressors can be either exogenous or endogenous:

- **Exogenous Stressors.** Stressors that arise from outside the policy system in the form of (1) sudden, unanticipated shock (e.g., 9/11, Hurricane Katrina, Hurricane Sandy) or (2) gradual, external long-term change that increases stress within a system to the point when it suddenly appears to make the existing way of doing business impossible (e.g., increasing energy prices, global change, growing public demands for environmental protection, changing economic conditions)
- **Endogenous Stressors.** Stressors that come from within a system (1) from changes in demands and resources produced by feedback within the policy system (e.g., the rise of the automobile and the growing pressure for new roads in the early 20th century leading to the Interstate system) and/or (2) from policy learning within the policy system, as members test out policies and identify those that are successful or fail (e.g., the revival of intercity public transit in the late 20th century)

Stressors generate pressure on organizational arrangements, undermine dominant paradigms, and raise the visibility of critical problems or challenges to the current paradigm. If the policy system is placed under sufficient stress, dramatic paradigm shifts can occur when the existing narrative no longer seems to adequately explain events and a new narrative needs to be created. If this occurs, new paradigms may emerge or existing (but dormant) alternatives may be developed. In this case, new relationships, policy paradigms, and policymaking arrangements are established which come to be accepted as the baseline for future policy change. For example, the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) radically changed the U.S. transportation community's balance of power (e.g., MPOs gained additional

authority and credibility), policy paradigms (e.g., single mode to multiple modes), and policy-making arrangements (e.g., two new categories of federal funds—the Congestion Management and Air Quality Improvement Program and the regional component of the Surface Transportation Program—were created, and a set of rules to use these funds were established).

This punctuated equilibrium model explains change within the transportation system. In general, the transportation policy system has been characterized by stable predictable changes punctuated by periods of rapid change. For example, prior to World War II, the states, localities, and the private sector dominated the transportation system. States developed the intercity road system and local governments and the private sector provided local roads, railroads, and most long-distance freight and passenger transportation infrastructure. In metropolitan areas, public transit systems, private street car companies, and private railroads delivered local transportation services. The federal government had been a relatively minor player in the transportation system. Some initial federal investment and regulation had occurred after World War I and during the New Deal, but state and local governments were dominant in transportation.

In terms of the punctuated equilibrium model, the policy system had entered a stable policy period. In the 1940s, however, this system became unstable when the demands of World War II illustrated its inadequacy to meet the stresses of global mobilization. In 1941, President Roosevelt responded by appointing the National Interregional Highway Committee, whose recommendation for a National System of Interstate and Defense Highways resulted in the Federal-Aid Highway Act of 1944. Its goal was to expand the interstate road system by the 1950s.[5] Thus, after a period of instability, the system changed and the federal government became the dominant player.

Using this as a model, the question becomes what would be needed to shift the policy system from the existing consensus toward a new consensus based around sustainability. The model obvious answer is some form of crisis or dramatic event. To understand what type of event might cause change, the research team reviewed more than 50 major economic problems, natural events, and political and military crises affecting the United States and identified the following characteristics that consistently seem likely to lead to major policy shifts:

- **Scope of impact.** The extent of the impacts of the crisis (both in the people affected and the potential future threats) influences the response strongly. For example, a major fire or tornado may produce a local/regional crisis but usually does not change significantly the broader allocation of responses or policy.
- **Magnitude of impact.** The larger the impacts of the crisis (e.g., property damage, loss of life), the more likely there is to be a major policy change, especially when these impacts are distributed over a wide region.
- **Control.** The degree to which the public believes that something could have been done to address or avoid a crisis, the more likely there is to be major policy change. So-called "acts of God" or random events are less likely to produce a major policy change than disasters deemed preventable.
- **Perceived probability of reoccurrence.** If an occurrence is perceived as low probability or rare (e.g., a major hurricane in New England), major policy change is less likely.
- **Effectiveness of response.** If the efforts to avert or mitigate major events are perceived as satisfactory, then major policy changes are unlikely.
- **Comprehension/understanding/technology.** A crisis is more likely to produce real change if its causes are well understood and if tools exist to avert or mitigate it. Crises that have a strong storyline, are easy to understand, and have clear solutions are more likely to lead to policy change than those that disappear from media coverage quickly.

[5] The Interstate and Defense Highways Act of 1956 (also known as the 1956 Federal-Aid Highway Act or Interstate Act) appropriated $25 billion (about $197 billion in 2009 dollars) to build 41,000 miles of multilane, limited-access highways.

- **Maturity of the policy system.** Established and (perceived as) effective policy systems have more "staying power" through major events. Either the public perceives setbacks and crises as rare, or the public rationalizes the policy system to have worked "well-enough" not to invest in change.

These findings explain why the policy systems and institutions associated with the transportation system generally are not prone to change in response to most shocks and short-term crises. In contrast to other policy systems (e.g., defense and national security, education, science and technology, environment), it is difficult for the transportation policy system to experience the dramatic system-wide crisis that can lead to sudden dramatic paradigm change.

Specifically, the public experiences transportation issues and challenges on a local and regional level. Although decaying infrastructure is viewed by the industry as a significant challenge nationwide, the public tends to recognize actual congestion and infrastructure problems regionally—and the issues are not obvious in all localities and regions. Thus, national transportation crises rarely occur. Even highly dramatic events and evidence of problems (e.g., the I-35W Mississippi River Bridge collapse of 2007, the Silver Bridge Collapse of 1967, the I-580 East Connector Collapse of 2007, infrastructure damage from major storms) tend to be seen by the public as local or regional events requiring local solutions, rather than as a call to invest in correcting widespread systemic failures. Instead, transportation issues emerge in public view as a slowly building crisis, and, as a result, momentum for change may take many years to build up.

This can be seen in the current shift among many transportation agencies toward sustainability-based programs. Some states and localities, responding to perceived local or regional problems that have undermined the dominant "car-first" paradigm, have moved to more sustainability-based programs (e.g., congestion and gridlock leading to policy innovation to get people out of cars and onto transit or using bikes seen in the Pacific Northwest and Northern California). In other states and localities, these stressors are experienced less and the pressure to change is not present. The danger of policymaking in these systems is that, as has happened elsewhere, by the time the stressors develop to a point when change is necessary, the system will have reached a breaking point and the resources will not be available to affect meaningful change. Thus, the challenge for policymakers is to act in a timely manner and possibly before public demand for change reaches broad consensus. Furthermore, while crisis-driven change may be the best hope for a sudden dramatic shift to sustainability-based transportation policies, it is unlikely to occur given the nature of transportation policy.

A much more likely scenario is endogenous change occurring through slow, gradual stresses and policy learning that build up public calls for action over time. For example, in the 1960s, demand grew for public participation in the planning process. This was expressed as growing frustration over the impacts of highways in urban areas (the so-called "Freeway Revolt"). Opposition to top-down freeway planning began as early as 1955, when the *San Francisco Chronicle* published a map of proposed freeways for the Bay Area. Local activists organized to oppose numerous elements of the plan, and, in 1959, the San Francisco Board of Supervisors canceled seven of ten planned freeways.

It was not until the 1970s, however, that the public involvement movement took off. In the 1970s, most of South Florida's expressway projects were canceled due to a public vote to divert funds from roads toward mass transit projects and toward the planned Miami Metrorail. Similarly, local opposition was the death knell of a number of freeway projects in metropolitan Atlanta that would have created an overwhelmingly complicated system of interchanges and might have destroyed or bisected entire neighborhoods (Schiller et al., 2010).

Parallel to this were increased demands for environmental protection. In 1973, environmentalists in Connecticut filed lawsuits that effectively killed construction of planned interstates and

expressways in the Hartford area. After these freeways were canceled, the State of Connecticut used those allocated funds to rebuild and expand existing freeways in the greater Hartford area. Similarly, environmental groups and the City of Bloomington long protested the completion of I-69 through southwest Indiana. Their opposition pitted them against residents in the southwest corner of the state and the cities of Evansville, Petersburg, and Washington, which long supported the highway's construction. For 40 years, opponents held up construction of I-69 through southwest Indiana through litigation, legislative maneuvering, and acts of vandalism, while the highway's supporters accused opponents of attempting to isolate them from the rest of the state. Ultimately, construction on I-69 began in 2008, with completion between Evansville and Bloomington scheduled for 2014.

At the same time, there was growing concern about mobility opportunities for special groups (minorities, poor, elderly, and persons with disabilities) and the impact of roads and cars on their freedom of mobility. For example, in the 1970s, an extension of the Davison Freeway in Detroit was proposed to connect I-96, the Jeffries Freeway, I-696, and the Reuther Freeway. Detroit neighborhoods revolted and opposed having the freeway cut through their neighborhoods, which consisted predominantly of the poor and minorities and had already experienced substantial impacts from road building. As a result, the City of Detroit passed a moratorium on freeway construction and rerouted the planned Jeffries Freeway.

These battles changed the top-down, technocratic planning process that had dominated transportation planning up to that point and opened it up to new participants and issues. Most importantly, the 3C process was established and then amended to require citizen participation at all stages of the process, and NEPA introduced the requirement for environmental impact statements. The 3C transportation planning process [jointly developed by the Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration, now the U.S. Federal Transit Administration] was developed to ensure that effective, coordinated multimodal transportation planning and project implementation would be conducted on a nationwide basis.

In this case, the key actors within the system were able to learn from their mistakes and begin to adopt and experiment with new policies as internal pressures forced new paradigm shifts and support for new policies began to emerge.

2.3 Moving from Past and Current Policy System Models to a TBL Sustainability System Model

Based on the information collected from practitioner interviews and the literature review (see Appendix D), the research team defined a series of policy system models that represents different levels along a continuum, ranging from the early Safe Mobility system model of the mid-20th century to a future TBL Sustainability system model. These models represent the gradual evolution that transportation agencies undergo to move toward supporting a more sustainable society. The policy system progression is in part based on history and on a future sustainable end state for functions that need to be executed in all the scenarios. The model of the transition policy system is postulated as a logical intermediate between where most agencies are now and the defined TBL end state. The purpose in constructing this framework was to define a TBL sustainability end state or objective that can serve to identify gaps between practices in the predominant current policy systems versus a policy system to support TBL sustainability.

The following sections describe each element of these policy systems. State transportation agencies (in general), leading local governments, the federal government, private-sector sustainability leaders, and sustainability leaders in other countries were characterized by applying these five levels. The team then conducted a gap analysis and identified potential strategies that would take state transportation agencies from their current level to a more advanced one.

The research team identified the following five levels that transportation policy systems may achieve in moving toward TBL sustainability:

- Level 0 Policy System—Safe Mobility
- Level 1 Policy System—Compliant Transportation
- Level 2 Policy System—Green Transportation
- Level 3 Policy System—Sustainable Transportation
- Level 4 Policy System—TBL Sustainability

The Safe Mobility system model is Level 0 because it does not address sustainability at all but is included to contrast how the traditional transportation policy system model differs from the sustainability-based or -aspiring models.

2.3.1 Policy System Models

Based on the public policy literature, the research team identified three distinct elements of a transportation policy system: (1) organizing principles, (2) policy paradigms, and (2) transportation agency roles. Table 9 shows the identifying characteristics of the elements for each policy system model evolving toward sustainability.

The first element concerns the organizing principles or core values for the policy system model. The organizing principles vary for each policy system model. As discussed previously, until the 1970s, the key role of transportation policy systems was to expand and support the mobility of people and goods. In the 1970s and 1980s, this changed to where transportation agencies were required by law to consider additional goals as part of their mission. The organizing principle began to focus on balancing mobility along with other legislatively required concerns, such as the environment, economic development, and various sociocultural concerns. Despite the broad social consensus behind these goals, the general orientation of culture and the core values of the

Table 9. Characteristics of transportation policy system models evolving toward sustainability.

Policy System Model	Characteristics		
	Organizing Principles	Policy Paradigms	Role of Transportation Agency
Level 0 Safe Mobility	Supports societal mobility	Favors government ownership and control of the transportation infrastructure	Infrastructure owner–manager and regulator
Level 1 Compliant Transportation	Supports societal mobility and compliance with environmental, economic, and social legislative requirements	Favors government ownership and control of the transportation infrastructure	Infrastructure owner–manager and regulator
Level 2 Green Transportation	Supports societal mobility and environmental, economic, and social needs—emphasizes environment	Favors government ownership and control of the transportation infrastructure	Infrastructure owner–manager and regulator
Level 3 Sustainable Transportation	Supports sustainable transportation	Favors partnerships between modal agencies and the private sector to influence policy and budget decisionmaking	Infrastructure planner, coordinator (some owner–operator and some private), and regulator
Level 4 TBL Sustainability	Supports societal sustainability	Agnostic on issues of ownership or control of transportation infrastructure—whatever is most sustainable	Infrastructure planner, coordinator (some owner–operator and some private), regulator, transportation system steward

transportation agencies were one of compliance. That is, balancing transportation needs against environmental concerns occurred because it was required by law rather than because it was a social good.

The Compliant Transportation policy system model evolved into the Green Transportation model. Under this model, there is wide support for balancing transportation needs with the environment. The model has moved beyond seeing environmental, economic, and social needs as merely requirements that must be followed and now accepts and supports their societal benefits.

While there is some support for sustainability (and frequently, even sustainability officers, programs, and metrics), sustainability is largely interpreted as environmental. In this system model, there is broad support for such issues as green procurement, green operations, green infrastructure, use of recycled or green materials, use of metrics and management systems that emphasize environmental progress, and a general bias toward considering environmental issues. Typically, the states most advanced in sustainability are at this level. That is, they are developing sustainability programs but still see it largely as an issue of environmental protection and balancing the environment against the demands of economic growth rather than true sustainability.

The Green Transportation policy system model is followed by a model that incorporates sustainability more consciously into transportation policymaking, planning, and delivery. However, the focus remains on "sustainable" transportation objectives within the control of transportation agencies—but still not overall societal sustainability. Some states have moved beyond "green transportation" to a sustainable transportation principle. The unspoken assumption is that if sustainable transportation is delivered, then societal sustainability will be delivered. This is a practical working assumption for DOTs that must operate within today's policy system and funding constraints—but it does not sufficiently support societal sustainability today. Some leading "sustainability" cities and local governments in the United States and around the world have been able to progress further toward a sustainable society at a local level, taking advantage of broader local investment influence and authority over multiple aspects of the local society.

At the final level, transportation agencies come to see that their organizing principle is to support the overall sustainability of society. Using safety and mobility as an example, a transportation agency's goals and standards for safety and mobility would be set by public demand and a balance of TBL considerations. This does not mean that the policy system in effect would not have standards and goals that must be met for safety and mobility, nor that agencies would not strive to optimize or maximize safety and mobility over and above those standards and goals. The observation does mean that, the public would demand and set appropriate safety and mobility standards *that meet the TBL sustainability policy system.* This illustration is borne out by the way that safety and mobility goals and standards have changed and evolved over past decades in evolving policy systems.

In the Level 4 policy system model (TBL Sustainability), the organizing principle would be to support the overall sustainability of society. This means that a transportation agency would accept and work toward delivering optimal mobility as defined by needs to balance the TBL. In such a case "optimal" would be defined by society, taking into account broader TBL priorities—as opposed to being defined mainly by transportation agencies. Clearly, in such a scenario, funding sources to meet society's transportation objectives would have to be broader than—and not constrained by—transportation-specific revenue sources. No state, local, national, or other entity currently operates in a Level 4 policy system.

Paralleling these distinctions reveals the evolution of different policy paradigms—that is, what is the best way to implement a particular core value or organizing principle? In the first three system models, the basic assumption is that the transportation agency is the owner and manager of the transportation infrastructure, i.e., the basic role of a transportation agency is as owner,

manager, and regulator. This role begins to change under the Sustainable Transportation system model. Under this model, there tends to be a move away from strict command and control toward a greater openness for decisionmaking partnerships with other agencies and the private sector. TBL Sustainability involves significant support and hard choices across social, economic, and environmental sector boundaries. The research team sees no logical way for this happening without those sectors having active seats at the decisionmaking table. TBL Sustainability would require mechanisms to share high-level strategy and funding decisionmaking consensus between transportation and nontransportation agencies and with some form of selected and authorized representation of the private sector (perhaps commissions, authorities, boards, counsels). Delivery approaches for programs and projects that emanate from these strategy and funding decisions are not a directly related issue, as delivery could involve many forms of agreements and contracts, command and control, or other concepts.

The need for partnership is both because of the initial investments needed and the distributed effects of major transportation programs and because TBL Sustainability requires substantial stakeholder and private-sector involvement if it is to be accepted and funded successfully. In this example, the transportation agency comes to play the role of coordinator and planner as well as the agency to deliver transportation programs to support a sustainable society.

Finally, the system evolves into a true societally sustainable model. Under this model, transportation agencies are agnostic on the issue of public or private ownership. Instead, they pursue any ownership and management combination that promotes societal sustainability successfully. Their role could more likely be one of development and stewardship of transportation resources.

The concept of stewardship is important to the TBL Sustainability model, but it is a difficult concept to define. The World Health Organization has developed a concept of stewardship that identifies six core domains for organizations to practice good stewardship (Travis et al., 2002):

- Generating intelligence and understanding of the policy area
- Formulating strategic policy direction
- Ensuring that the tools exist for the implementation of policy
- Building coalitions/partnerships
- Ensuring a fit between policy objectives and organizational structure and culture
- Ensuring accountability

This concept fits well for transportation. Under a TBL Sustainability system model, a transportation agency would retain full responsibility for transportation services and stewardship by collecting data, developing intelligence, and understanding transportation needs and how they affect societal sustainability; formulating strategic policy; developing tools for implementation; building support for policy; developing the appropriate structures to implement policy; and ensuring responsiveness and accountability. While always remaining responsible and accountable for infrastructure delivery and operation, DOTs may not necessarily design, build, or operate the transportation infrastructure in the ways typically followed today.

2.3.2 Inputs to the Policy System

As discussed in Section 2.1.1, there are two main inputs to any policy system: demands and resources. In the case of transportation, there is a gradual evolution—of demands from mobility, accessibility, safety, and economic development—to TBL Sustainability. Table 10 illustrates this evolution. The system moves from a situation where the public, stakeholders, and political entities demand a simple good (mobility and economic growth) to one where the demand is for additional goods, such as environmental protection, protection of sociocultural assets, and public participation.

Table 10. Inputs to transportation policy systems evolving toward sustainability.

Policy System Model	Inputs	
	Public Demands and Priorities	Resources
Level 0 Safe Mobility	1. Mobility 2. Safety 3. Economic development	• Gas tax, excise taxes, and impact and licensing fees • Intergovernmental transfers • Bond issues • Some user fees (e.g., toll roads)
Level 1 Compliant Transportation	1. Mobility 2. Safety 3. Economic development 4. Environmental compliance 5. Other (e.g., heritage and culture protection) 6. Public participation Note: Each is seen as a separate demand.	• Gas tax, excise taxes, and impact and licensing fees • Intergovernmental transfers • Bond issues • Some user fees (e.g., toll roads)
Level 2 Green Transportation	1. Mobility 2. Accessibility 3. Safety 4. Economic development 5. Environmental compliance 6. Other (e.g., heritage and culture protection) 7. Public participation Note: Each is seen as a separate demand.	• Gas tax, excise taxes, and impact and licensing fees • Intergovernmental transfers • Bond issues • Some user fees (e.g., toll roads)
Level 3 Sustainable Transportation	1. Sustainability (TBL): 1.1. Environment 1.2. Economy 1.3. Social well-being (includes quality of life, accessibility, safety and security, and preservation of natural resources) 2. Mobility and safety 3. Accessibility 4. Connectivity 5. System efficiency 6. Public participation Note: Tradeoffs are possible.	• Gas tax, excise taxes, and impact and licensing fees • Intergovernmental transfers • Bond issues • Substantial use of user fees and market mechanisms
Level 4 TBL Sustainability	1. Sustainability (TBL): 1.1. Environment 1.2. Economy 1.3. Social well-being (includes quality of life, accessibility, safety and security, preservation of national resources) 2. Mobility and safety 3. Accessibility 4. Connectivity 5. System efficiency 6. Public engagement Note: Tradeoffs are possible.	• Self-financing (e.g., user fees, tax on vehicle miles traveled, infrastructure banks) • Intergovernmental transfers

During this transition from Compliant Transportation and Green Transportation to Sustainable Transportation and then TBL Sustainability, the public would begin to demand a sustainable TBL balance and to set goals for risk and performance along each of the bottom lines. At the next level of the evolution (TBL Sustainability), the public demand recognizes the need to balance and optimize TBL, while demanding that standards and goals for risk and performance along each bottom line are met or exceeded. When tools and methods reach a level of sophistication to support this policy system, strategic decisions and priorities based on TBL considerations (and communications on these) could be practical.

Under the first three policy system models, the main resources that are provided to the transportation system are (1) gas taxes, excise taxes (e.g., tax on tires), and impact and licensing fees;

(2) intergovernmental transfers (e.g., grants, revenue sharing, direct financing of projects); (3) bond issues; and (4) user fees (e.g., toll roads). Under the Sustainable Transportation system model, these funding sources are expanded to include broader sources. In addition to the general fund, more user fees could be assessed, possibly linked to societal benefits not traditionally linked to transportation. There would also be more widespread use of market mechanisms to achieve goals and finance the transportation system. There might also be a much greater move toward partnerships, where government might oversee system development under traditional processes, and then transfer operation of some assets to a private organization for service delivery or to provide income for additional projects.

Under a truly sustainable system, transportation could be more directly financed by users of the system based on where, how, and how much they use the system. The presumption is that users in a region, or users that are part of a particular user segment, will have much more to say (through representatives elected or otherwise commissioned) about how and where the funds should be invested for sustainable transportation or other services that are important to them. This could be achieved through a mixture of user fees (e.g., congestion charges, tolls, taxes on vehicle miles traveled). This system of funding would also be more amenable for financing through some semipublic system (a bank) or public–private investment strategy that can depend on a flow of revenues from the transportation system to service debt.

2.3.3 Actors and Their Relationships

Table 11 shows the role of actors under different models. As can be seen, most governmental actors are major players under all models. Local governments, MPOs, nontransportation state agencies, and other modal authorities increase in importance gradually as the transportation policy systems move from a purely transportation focus to a societal sustainable focus.

Similarly, economic interests are always important. Economic interests include major state and local businesses, small businesses affected by transportation decisions, providers of transportation services (e.g., freight companies and shippers, private transit providers, railroads, and airlines concerned about local intermodal connections), firms involved in highway construction activities, land developers and builders, trade unions, and other entities with (1) a substantial, ongoing interest in the continued economic growth and development of a state and (2) an interest in the distribution of transportation resources to the benefit of one party or another.

These interests are always and inevitably active in transportation policymaking and implementation. They influence policy via a number of mechanisms, including formal and informal participation in the development of the goals of state transportation policy (e.g., participation in elections by supporting one candidate versus another; participation in state legislative hearings, blue ribbon panels, and other mechanisms to solicit input for key local interests; formal participation in consultative processes). Furthermore, because one of the key goals of transportation policy is to support the economic development and growth of an area, transportation agencies must understand and respond to the economic interests' competing visions of the transportation system's future. This does not mean that economic interests control or direct policy. Rather, they are an important and inevitable constituency that must be considered in policymaking and will always be a major consideration in how policy is developed and implemented.

The major change that occurs as the system moves from a Safe Mobility model to a TBL Sustainability model is the involvement of civic and social groups. Previously, these groups were involved only in the initial stages of the policymaking process. Specifically, prior to the 1970s, their activities (to the extent they existed at all) were confined to the initial formal and informal political processes (e.g., participating in elections, lobbying elected representatives, testifying before legislative committees). With the emergence of the modern environmental movement

Table 11. Actors and relationships in transportation policy systems evolving toward sustainability.

	Level 0 Safe Mobility	**Level 1** Compliant Transport.	**Level 2** Green Transport.	**Level 3** Sustainable Transport.	**Level 4** TBL Sustainability
GOVERNMENTAL SECTOR					
State legislature, individual legislators, legislative committees	●	●	●	●	●
Governors	●	●	●	●	●
Transportation commissions (if present)	●	●	●	●	●
U.S. DOT and other federal transportation agencies	●	●	●	●	●
Other federal departments (e.g., Environmental Protection Agency)	●	●	●	●	●
State DOTs	●	●	●	●	●
MPOs	◔	◔	◑	●	●
Local governments	◑	◑	◑	●	●
Other state government agencies	◔	◔	◑	◑	●
Other modal authorities (e.g., airports, ports, passenger rail)	◔	◔	◑	●	●
PRIVATE SECTOR					
State and local economic interests and businesses	◔	◔	◑	◕	●
Transportation providers and system operators	◔	◔	◑	◕	●
INTEREST GROUPS					
Community and civic groups (e.g., community booster groups, chambers of commerce)	○	◔	◕	●	●
Environmental groups	○	◔	◕	●	●
Professional organizations and research organizations	○	◔	◕	●	●
Single-issue transportation groups	○	◔	◕	●	●
Social, economic, ethnic, and cultural interest groups	○	◔	◕	●	●

KEY:

○ No involvement in the policy process

◔ Minor involvement in the policy process

◑ Regular involvement in the policy process

◕ Significant involvement in the policy process

● Key actors in the policy process

and local citizens' activist groups in the 1960s, they became more involved. The NEPA process, as well as the state and local versions of the Federal Administrative Procedures Act, gave civic and social interest groups more access to and involvement in the policymaking and implementation processes. Their involvement was strengthened further by their use of the courts and legal system and by direct action (e.g., picketing, land occupations, marches) to resist and delay transportation projects.

As the policy system develops toward a more sustainable system, civic and social groups need to become more integrated into the policymaking and implementation processes. The literature

review of successful experiences of sustainability shows that involving civic and social groups from the beginning of the process through implementation is vital to both developing a coalition that will support the process and ensuring it is designed to meet community needs. As the policy system moves from a Safe Mobility to a TBL Sustainability model, public participation and involvement in all levels of policymaking and implementation needs to increase.

In terms of the relationship between these groups, the processes in Safe Mobility through Green Transportation policy systems manifest similar power and organizational relationships. In Safe Mobility systems, policymaking and implementation are fundamentally hierarchical, siloed, and linear. That is, elected political entities (e.g., governors, legislatures) decide and determine policy and goals; agencies implement policy with minimal public input and involvement from other agencies; while the federal government provides funding, basic standards, and technical assistance. In Compliant Transportation policy systems, the same overall process occurs; however, there is an active effort to elicit public input during the planning phase. This effort expands in both Green Transportation and Sustainable Transportation policy systems, in which the policy systems become fundamentally more interactive, iterative, and flexible. Agencies work with elected bodies in a cooperative back and forth; mechanisms exist to engage and involve interest groups and citizens to develop goals, policies, and plans at all stages; and transportation agencies work with private sector entities to manage land use and transportation demand cooperatively. The federal government still provides regulation, funding (perhaps more limited), basic standards, and technical assistance.

Under any scenario, *with or without TBL sustainability*, surface people transportation (any mode) is seen as fundamentally a regional, state, corridor-specific, or local service—with linkages providing interregional travel when needed. Freight travel can also be seen as mainly regional or corridor specific but with a much higher proportion of interstate and international travel than people transport. In the long term, policymaking authority will be linked to how, where, and from whom revenue is collected and to how the payers influence allocation of the funds. If user charging for infrastructure continues to evolve to meet infrastructure needs, funding responsibility (and policymaking) is expected to *shift in the direction* of the regional, state, corridor, and local users that pay more and more of the tab for the service. High-speed intercity passenger rail is a good example of projects that can be (and probably already are) driven primarily by region-specific or corridor-specific needs and revenue models. The federal government will always have national public safety, security, defense, mobility, and interstate commerce interests and regulatory leverage on the infrastructure—but leverage on funding and transportation planning will likely gravitate toward the regions, states, and localities that will be paying directly for use of the infrastructure.

Finally, in TBL Sustainability systems, policymaking and implementation will need to be more integrated. As with Sustainable Transportation systems, policymaking and implementation processes are open to the public and organized interests, but other state, local, regional, and federal agencies will have to be explicitly involved and integrated into decision processes. Thus, under a TBL Sustainability system, transportation policy is linked explicitly to broader societal sustainability and policymaking is coordinated and managed in the broader context of the societal goals. Table 12 summarizes these relationships.

2.3.4 Functions: Developing Consensus on Needs and Goals

Table 13 shows the function of developing consensus as needs and goals evolve under different policy systems. As can be seen, the process evolves from a fundamentally reactive system to an interactive, flexible open system. That is, in a Safe Mobility policy system, policymaking is essentially reactive. The process is driven by political decisionmakers and major stakeholders

Table 12. Relationships between major actors under different policy system models.

Policy System Model	Characteristics
Level 0 Safe Mobility	Hierarchical, linear—fundamentally a linear process—Elected bodies decide policy and goals, and agencies implement with minimal public input and involvement from other agencies. Federal government provides funding, basic standards, and technical assistance.
Level 1 Compliant Transportation	Hierarchical, linear—fundamentally a linear process—Elected bodies decide policy and goals, and agencies implement with active effort to elicit public input; limited involvement from other agencies. Federal government provides funding, basic standards, and technical assistance.
Level 2 Green Transportation	Hierarchical, linear—fundamentally a linear process—Elected bodies decide policy and goals, and agencies implement with active effort to elicit public input; limited involvement from other agencies. Federal government provides funding, basic standards, and technical assistance.
Level 3 Sustainable Transportation	Interactive, iterative, flexible—Agencies work with elected bodies, interest groups, and citizens to develop goals, policies, and plan. Public involvement at all stages. Federal government provides funding (more limited), basic standards, and technical assistance.
Level 4 TBL Sustainability	Integrated, interactive, iterative, flexible—Agencies work with elected bodies, interest groups, and citizens to develop goals, policies, and plan. Public involvement at all stages. Mechanisms exist for all agencies to be consulted and involved in transportation planning. Federal government provides funding (more limited), basic standards, and technical assistance.

(e.g., key economic interests, important electoral groups). Once the policy has been made, a fundamentally technocratic process occurs in which experts implement policy that has been defined by the political leaderships. As the policy system moves toward a Compliant Transportation system model, it becomes more open. In this system, transportation agencies attempt to elicit comments and inputs from economic interests and civic and social groups; however, their involvement is confined fundamentally to the initial stages of the process or to carefully, legally defined opportunities. Transportation agencies view this process as disconnected from the rest of the policy process, because inputs are received from the public and little effort is spent on outreach, shaping public opinion, or developing consensus. Furthermore, public involvement is carried out as part of the legal process rather than as a vital part of the policy process. It is something that must be done as part of a legal mandate rather than to improve policymaking.

In a Green Transportation system, public involvement expands. The system seeks to become responsive to public involvement. Public involvement in the needs assessment process is seen

Table 13. Developing consensus on needs and goals under different policy system models.

Policy System Model	Characteristics
Level 0 Safe Mobility	Driven by political decisionmakers, public, and stakeholders to identify transportation needs—waits for stakeholders to identify demands—once identified, public participation limited to formal, legally required processes.
Level 1 Compliant Transportation	Attempts to elicit demands from stakeholders on pre-existing plans—allows commentary, but not much vehicle for implementing public feedback. Little outreach or consensus building.
Level 2 Green Transportation	Elicits demands from stakeholders and mandates. Outreach and consensus building occurs.
Level 3 Sustainable Transportation	Works with stakeholders to identify and prioritize demands—tries to balance against sustainability goals. Developing consensus is a major goal. Active outreach and consensus building.
Level 4 TBL Sustainability	Approaches decisionmakers and stakeholders proactively with goals and plans to support transportation needs sustainably. Developing consensus is a major goal. Active outreach and consensus building.

as vitally important and considerable effort is devoted to outreach and consensus building. This expands during the Green Transportation phase; then there is a substantial, continuous effort to involve the public not only in responding to plans but also in helping to develop them, identify and prioritize demands, and work toward a consensus. This climaxes in Sustainable Transportation systems, when all major interests are actively involved in developing goals and trading off between different goals. In doing so, the public and major stakeholders take ownership of these tradeoffs and understand and support the outcomes.

A good example of public participation and consensus building in Green Transportation and the Sustainable Transportation phases is shown in the experience of Boulder, Colorado. During the 1980s, the political and community leadership decided that a new approach to transportation was needed. As a result, the City of Boulder sponsored a series of planning conferences that brought together citizens, interest groups, and experts to discuss Boulder's transportation needs. These conferences involved more than 70 stakeholder groups, including the Sierra Club, PLAN-Boulder County, the Environmental Defense League, the Chamber of Commerce, the League of Women Voters, and numerous community and neighborhood groups. The result was a new Transportation Master Plan that had the main goal of shifting 15 percent of single occupancy vehicle (SOV) trips to other modes by 2010. The broad consensus reached during these conferences and the practicality of the approach adopted meant that these goals were largely achieved (Project for Public Spaces, Inc., 1997; Schiller et al., 2010).

This form of citizen participation in identifying needs is not limited to the initial stages of the planning process but can be carried on throughout the implementation process to encourage support for and implementation of transportation policies. For example, Seattle has been very successful in implementing traffic circles by involving the public in their siting and maintenance. The City of Seattle invited neighborhood residents to analyze their street problems. It provided them with the technical assistance to conduct these analyses and then encouraged them to submit a proposal if they found that traffic circles would be a useful response to their problems. Once a traffic circle was constructed, the City solicited volunteers from the local community to maintain the traffic circle as a garden spot and provided them with tools, plants, and soil to maintain it (Schiller et al., 2010). Similarly, the City of Portland, Oregon, engages citizens in a repair process. A number of citizen-organized groups responded to declining pedestrian conditions at local intersections by repairing and improving these intersections on their own. The City adopted their efforts, changed policy to respond to their needs, and involved them in the planning and improvement process. As a result, citizens now organize local celebratory events around intersections, decorate public intersections, and agree to support ongoing maintenance with their own labor (Schiller et al., 2010).

Another characteristic of Green Transportation and Sustainable Transportation policy systems is that transportation agencies move beyond being either technocratic managers of public demand or passive responders to politically articulated demands to becoming active in defining and developing public demands and requirements. This helps build a constituency for sustainability. Elder and Georghiou (2007) note that there are many tools available to the public sector to create and manage demand for specific policies and services. These include leveraging public procurement, direct provision of financial incentives to support certain behaviors, awareness building, competence building, information provision, and regulatory interventions. For example, tax incentives to adopt electric vehicles are likely to create increasing market pressures for charging stations and lead to increasing demands on the government to adopt policies that encourage the provision of charging stations. Thus, correctly designed public policy can create a virtuous circle, where initial nudges toward a socially desirable behavior can lead to demands for further governmental action that will reinforce and encourage that behavior.

The news media relentlessly criticized Portland, Oregon's light rail transit, known as the Metropolitan Area Express, during its planning and construction; however, the system has

become such a success that arguments about building extensions have ceased. Now, these communities argue over which should receive an extension (Schiller et al., 2010). Thus, initial public investment and communication made the public more aware of the benefits of sustainability and led to expanded demands for sustainable transportation. In terms of sustainability initiatives, the point is to recognize (1) that the initiative itself can act to shape and define demand and (2) that all initiatives (e.g., regulation, procurement, and outreach) need to be part of an overall strategy to build support for sustainability policymaking.

2.3.5 Functions: Planning and Programming

Table 14 shows how planning and programming evolve through numerous changes from Safe Mobility to TBL Sustainability policy system models. During Safe Mobility, the system focuses fundamentally on the development of one mode (the automobile) and emphasizes quantity and mobility (more roads, faster transportation). Planning follows anticipated travel demands and a "predict and provide" mindset, where travel demand is forecast and then plans are made to provide transportation to meet that demand. Transportation planning is siloed from other governmental functions and is not linked to land use decisions. Performance measures and metric systems are confined to specific transportation-related metrics and do not attempt to capture the broad social and economic impacts of the transportation policies. Furthermore, transportation planning is limited to a single jurisdiction. Regional or megaregional planning and programming are extremely limited, and the extra-jurisdictional impacts of plans are not considered.

As the system evolves, there are slow, gradual changes. At first, formal and informal links are built with other agencies and planning entities (e.g., local governments, other modal authorities, MPOs) to coordinate planning under Compliant Transportation and Green Transportation. By Sustainable Transportation, a new approach to planning has emerged. Under this approach, the system now emphasizes flexibility, accessibility, connectivity, and quality (closer, better); emphasizes multiple modes and connections between modes; manages transportation and mobility demand; uses analysis to interrupt and reverse trends; works from preferred vision to planning and provision (deliberate and decide)—in particular, building scenarios, backcast; and makes planning and investment decisions using reliable and up-to-date data that reflect the full range of impacts from investing in transportation.

In terms of planning itself, TBL Sustainability requires a change in the specific techniques, time horizons, and disciplinary expertise used. For example, Table 15 shows that the elements of the planning process need numerous changes to incorporate sustainability.

In terms of the break between predict and provide/accept and accommodate and deliberate and decide/predict and prevent, several tools are available to help decisionmakers move toward a more sustainability-based system. For example, scenario planning and backcasting have been found to be useful tools for sustainability planning (Schiller et al., 2010). Backcasting is especially useful, because it starts with defining a desirable future and then works backward to identify policies and programs that will connect the future to the present. It treats the future as the past and asks, "Given attainment of a certain goal, what actions must have been taken to get here?" Figure 4 shows the difference between forecasting and backcasting. By separating policy makers from the present, the technique allows policy makers to free themselves from developing a vision of the future limited by today's realities and forces them to think into the future and then work backward to identify the route to get there. This technique has been used in a number of sustainability initiatives. For example, the Capital Regional District Water Services, which serves the greater Victoria area in British Columbia, Canada, committed to backcasting to the year 2050 as a formal element of all future strategic water planning initiatives.

Table 14. Planning and programming under different policy system models.

Policy System Model	Characteristics
Level 0 Safe Mobility	• Emphasizes mobility, safety, and quantity (more, faster). • Emphasizes one mode (unimodal, automobility). • Expands in response to travel demand (accept and accommodate). • Transportation planning is siloed and disconnected from environmental, social, and other planning areas. • Transportation planning is not connected to land use decisionmaking. • Plans and builds based on forecasts of likely demand (predict and provide). • Limited by political jurisdiction. • Limited data and related performance measures to support current planning goals, objectives, and investment decisions.
Level 1 Compliant Transportation	• Emphasizes mobility, safety, and quantity (more, faster). • Emphasizes multimodal and connections between modes. • Expands in response to travel demand. • Transportation planning is siloed and disconnected but considers environmental, social, and other planning areas. • Transportation planning is not connected to land use decisionmaking. • Plans and builds based on forecasts of likely demand (predict and provide). • Limited by political jurisdiction. • Limited data and related performance measures to support current planning goals, objectives, and investment decisions.
Level 2 Green Transportation	• Emphasizes mobility, accessibility, safety, and quantity (more, faster) but considers flexibility, connectivity, system efficiency, and quality (closer, better). • Emphasizes multimodal and connections between modes. • Manages transportation and mobility demand. • Formal and informal links exist between other planning entities in other governments (e.g., local, regional, federal) and agencies (e.g., environment). • Plans and builds based on forecasts of likely demand (predict and provide). • Limited by political jurisdiction. • Compliance-based reporting.
Level 3 Sustainable Transportation	• Emphasizes flexibility, accessibility, connectivity, system efficiency, safety, security, and quality (closer, better). • Emphasizes multimodal and connections between modes. • Manages transportation and mobility demand. • Uses analysis to interrupt and reverse trends. • Works from preferred vision to planning and provision (deliberate and decide)—build scenarios, backcast, deliberate, and decide. • Planning and investment decisions are driven by reliable and up-to-date data that reflect the full range of impacts from investing in transportation.
Level 4 TBL Sustainability	• Emphasizes flexibility, accessibility, connectivity, system efficiency, safety, security, and quality (closer, better). • Emphasizes multimodal and connections between modes. • Manages transportation and mobility demand. • Relates planning and programming to wider objectives. • Emphasizes integrated planning combining transportation (all modes) with other relevant areas (environment, demographic trends, cultural resources) and levels of government. • Uses analysis to interrupt and reverse trends (predict and prevent). • Works from preferred vision to planning and provision (deliberate and decide)—build scenarios, backcast, deliberate, and decide. • Flexible regional focus that engages multiple jurisdictions. • Planning and investment decisions are driven by reliable and up-to-date data that reflect the full range of impacts from investing in transportation.

Table 15. Planning techniques and requirements.

	Characteristics	
Planning Element	Green Transportation	TBL Sustainability
Time scale	10–15 years	Intergenerational (>30 years)
Time frame	Static	Dynamic
Spatial orientation	Single jurisdiction	Regional, multijurisdictional
Disciplinary focus	Transportation engineering	Multidisciplinary
Data	Quantitative	Quantitative and qualitative
Approach	Reactive Predict and provide	Proactive (precautionary principle) Predict and prevent Deliberate and decide

Source: Adapted from Zuidgeest et al. (2000).

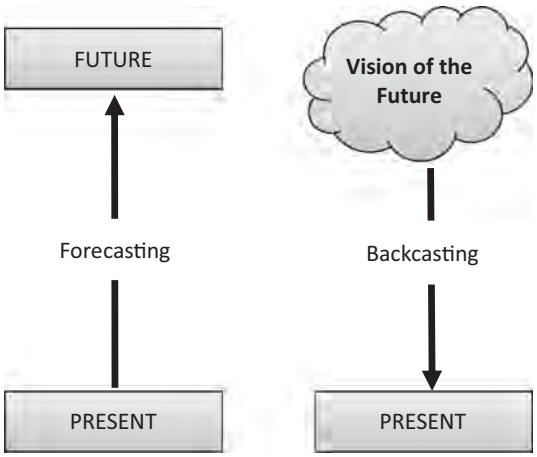


Figure 4. Backcasting versus forecasting.

2.3.6 Functions: Budgeting and Resource Allocation

Table 16 shows the evolution of budgeting and resource allocation systems under different policy system models. The process evolves from a fundamentally antagonistic, competitive system that is highly siloed and inflexible and ignores larger social costs to a system that is integrated and flexible and incorporates the full social, economic, and environmental costs. Note that states and

Table 16. Budgeting and resource allocation under different policy system models.

Policy System Model	Characteristics
Level 0 Safe Mobility	• Budget process is competitive (e.g., agencies compete for funds), siloed, and driven by previous allocation decisions (e.g., last year's budget is always the template). • Ignores larger social, regional, and economic costs and benefits of transportation—focuses on immediate cost–benefit analysis. • Inflexible—funds are bucketed and segregated by legal requirements. • Politicized—transportation funding is driven by prevailing trends in politics.
Level 1 Compliant Transportation	• Budget process is competitive (e.g., agencies compete for funds), siloed, and driven by previous allocation decisions (e.g., last year's budget is always the template). • Focuses primarily on immediate direct costs but does include social, regional, and economic costs and benefits of transportation. • Inflexible—funds are bucketed and segregated by legal requirements. • Politicized—transportation funding is driven by prevailing trends in politics.
Level 2 Green Transportation	• Budget process is competitive (e.g., agencies compete for funds), siloed, and driven by previous allocation decisions (e.g., last year's budget is always the template). • Incorporates full social, environmental, fiscal, economic, and other costs into planning and provision—uses full cost accounting (FCA).
Level 3 Sustainable Transportation	• Budget process is integrated and cooperative. • Incorporates full social, environmental, fiscal, economic, and other costs into planning and provision—uses FCA. • Independence—funds for transportation are obtained from a politically neutral infrastructure reserve.
Level 4 TBL Sustainability	• Budget process is integrated and cooperative. • Incorporates full social, environmental, fiscal, economic, and other costs into planning and provision—uses FCA. • Flexible—funds flow to program areas, regions, and modes where they will make the biggest impact on societal sustainability. • Independence—funds for transportation are obtained from a politically neutral infrastructure reserve.

localities operate under different budgetary rules and processes [see Head and Sigritz (2008), which describes all the budgeting processes in the 50 states and District of Columbia]. In fact, there are more than 85,000 governments in the United States, including the federal government, 50 state governments, and local governments. Generalizations become difficult when one discusses any government function and its variations. A true analysis of how all these systems must change to support sustainability would require an extremely detailed analysis, which is beyond the scope of this report. Therefore, the research team concentrated on key indicators of changes and identified specific techniques that might be useful in moving toward sustainability.

2.3.7 Functions: Regulation and Rulemaking

Table 17 shows the evolution of regulation and rulemaking from Safe Mobility to TBL Sustainability policy system models. The system progresses from one that is technocratic, led by experts, and heavily influenced by economic and organized interests with minimal public involvement to one that is much more open and flexible.

"Rulemaking" refers to the process executive and independent agencies use to create regulations. In general, legislatures first set broad policy mandates by passing statutes, and agencies then create more detailed regulations through rulemaking. Transportation is subject to a variety of regulations affecting topics that include safety standards for different modes of transportation and cargo, operational requirements (e.g., speed, maintenance, driver qualification and hours of service, equipment, employee safety and health, transportation of hazardous materials), registration and record keeping, traffic control, and the environmental impacts of transportation. Numerous regulations also affect transportation, although they are not targeted primarily at transportation. For example, due to the importance of transportation as a contributing source of air pollution, clean air regulations affect transportation directly. Water runoff regulations affect roadways, because highway runoff contains pollutants that eventually reach off-road bodies of water. Rulemaking and regulation are major functions of state transportation systems.

Table 17. Regulation and rulemaking under different policy system models.

Policy System Model	Characteristics
Level 0 Safe Mobility	• Led by experts • Heavily influenced by organized interests and economic stakeholders • Minimal public involvement
Level 1 Compliant Transportation	• Led by experts • Heavily influenced by organized interests and economic stakeholders • Increased public involvement • Highly politicized and conflict based
Level 2 Green Transportation	• Led by experts • Open to a plurality of interests, stakeholders, and activists • Substantial public involvement during post-decisionmaking phase (i.e., do you approve?) • Highly politicized and conflict based
Level 3 Sustainable Transportation	• Public–expert partnership in developing regulation and rules—experts invite and encourage public participation • Open to a plurality of interests, stakeholders, and activists • Substantial public involvement during the entire rulemaking process • Less politicized and cooperative
Level 4 TBL Sustainability	• Public–expert partnership in developing regulation and rules—experts invite and encourage public participation • Open to a plurality of interests, stakeholders, and activists • Substantial public involvement during the entire rulemaking process • Less politicized and cooperative • Flexible regulation that balances difference goals and processes

As promulgators of new regulations and implementers of federal regulations, the states play a key role in the process, and regulation drives a substantial amount of state transportation activities. As such, any movement toward sustainability will require major changes in the rulemaking and regulation processes.

This section outlines the current process used in many states, describes the core characteristics of this process in regard to transportation, identifies how this may change under sustainability, and describes the gaps between these states (i.e., current, conventional, and sustainable operations).

Early regulation of transportation began at the state level. Before the emergence of the U.S. DOT and the federal regulatory system, the states were the main actors in transportation regulation. Initially, state regulation developed out of the common law concept of business affected with the public interest. With the railroad age, however, state statutory regulation emerged with the development of various granger laws to regulate railroad rates and service. In the early 20th century, state regulation played a key role in standardizing U.S. road and car operations and laid the framework for many succeeding federal regulations. In the later 20th century, the involvement of the federal government in transportation meant that many states had to expand their rulemaking activities to develop regulations that met federal requirements and brought their systems into compliance with national standards (frequently under the threat of federal funding loss or inducement for additional funding).

Paralleling these trends was a greater movement at both the federal and state levels toward greater openness and standardization of the rulemaking process. In general, the goal was to open the rulemaking process to the public and affected parties and increase the transparency and accountability of government. In support of this, numerous legislative requirements were established to demonstrate the economic benefits of regulation and to place regulation on a more standardized, predictable, and scientific basis. This legislation follows a number of general principles:

- The agency promulgating the rule should be able to demonstrate that it has used the administrative discretion granted it by the authorizing statute to create a regulation that processes net economic and social benefits, is informed by the best available information and scientific and technical insight, and has explained clearly how the authorizing statute justifies the proposed rule.
- Rulemaking should follow general rules of due process.
- The public should be informed of *proposed rules* before they take effect.
- The public should have the opportunity to comment on the proposed rules and provide additional data to the agency.
- The public should be able to access the *rulemaking record* and analyze the data and analysis behind a proposed rule.
- The agency promulgating the regulation should analyze and respond to the public's comments.
- The agency promulgating the regulation should create a permanent record of its analysis and the process.
- To ensure the correct process was followed, a judge or others may review the agency's actions.

The result was a series of statutes at the state and federal levels that mandated a standardized process for developing and promulgating regulations. For the purposes of this study, the following characteristics of this process are key:

- **Highly structured, legalistic process.** The current rulemaking process is highly structured and legalistic. Regulations emerge from a standardized, routine process that identifies the requirements for each stage of the process and controls the degree of interaction between different actors in the process (e.g., when and where in the process the public and affected parties may

be heard). As a result, arguments about regulations degenerate frequently into discussions of the process and whether it has been followed. Furthermore, the openness of the process to the public and affected parties (via the public comment period and the opportunity for judicial review) means that opponents of regulations have numerous opportunities to challenge or influence rules. The result is that rulemaking can often be stymied by numerous efforts to slow down or halt proposed changes and that the structure of the process discourages cooperation and encourages legalistic opposition frequently.

- **Confrontational system.** The regulatory system in the United States is characterized by a high degree of confrontation. During the research team's interviews with transportation agencies, a number of agency staff members emphasized that their regulatory actions are often accused of too heavily favoring industry, environmental groups, or particular interests. Honest debates over regulatory standards can degenerate to name calling and a perception that whatever final decision is made, it has been made in the interest of one party or another. Facing this, agencies tend to retreat into process-based decisionmaking, where one justification for the decision becomes that the agency has complied with the required process.
- **Prescriptive and process-based outcomes.** Current regulatory efforts tend to mandate specific actions to be undertaken and describe how they should be undertaken. The rationale for this is that the problems that regulations attempt to address are complex and the affected parties naturally try to evade regulatory costs; therefore, regulations must be either overly complex (to specify exactly what regulated parties should do) or overly simplistic (where inflexible mandates are introduced in an effort to avoid ambiguity). The result is that regulatory compliance costs tend to increase and further confrontation and resistance are encouraged.

One of the key challenges to this process that TBL Sustainability will require is the development of flexible standards that can consider tradeoffs between different elements of the TBL. This development will require regulators to understand the following:

- The opportunities for potential tradeoffs between different regulatory and policy initiatives (i.e., how to establish standards between competing regulations and policy alternatives to achieve optimal sustainability, while not overly burdening regulated parties)
- The abilities of, and opportunities for, regulated entities to achieve sustainability goals within the constraints of their budgets

This situation has double information asymmetry:

- **Regulatory agencies** can understand the necessary big-picture tradeoffs between different regulatory options and potential methods for regulated parties to comply *but lack information* on the specific circumstances of individual regulated parties and the options for compliance they may face.
- **Regulated parties** (e.g., individual firms, local governments, households, individuals) have detailed information about their individual situation and options for complying with regulations *but lack information* on potential innovative methods to comply or how their apparently minor actions may affect the overall sustainability equation when acting collectively.

Information asymmetry occurs often in regulation, but the asymmetry is worsened when sustainability is at issue. For sustainability, the options for compliance, potential tradeoffs, and potential impacts increase exponentially over traditional regulatory problems. One proposed response is to increase the number of voluntary or negotiated rulemakings. Under this system, regulatory agencies and affected parties negotiate voluntary codes of compliance that embrace a wide variety of behaviors and options. Table 18 shows the range of potential voluntary regulatory arrangements that could be used to replace more top-down regulation and rulemaking.

Table 18. Sample voluntary rulemaking and regulation arrangements.

Type of Arrangement	Key Features	Examples
Individual Firm Standards	Unilateral action on dimensions of environmental performance chosen by the firm	3P—Pollution Prevention Pays
Trade Association	Specific actions or codes of conduct agreed upon by at least a large segment of an industry	Keidanren Voluntary Action Plan, Chemical Industry Responsible Care Program
Cross-Industry Efforts	Codes of conduct or commitments designed by industry to address performance across a range of industries	International Chamber of Commerce, Global Environmental Management Initiative
Standards Organization	System for verifying performance through third-party certification	International Organization for Standardization 14000
Nongovernmental Organization	Voluntary codes of conduct developed by organizations focused on objectives for corporate social responsibility	Coalition for Environmentally Responsible Economies Principles
Government-Led Voluntary Challenges	Opportunities for firms to take voluntary action and receive technical assistance in coordinating with other actors and public recognition	Energy Star SmartWays
Government-Led Voluntary Agreements (Negotiated Rulemaking "Reg-Neg")	Contractual agreement, in lieu of regulation or as part of regulation	European Union voluntary regulatory agreements

The advantage of these arrangements when applied to sustainability is that they leverage the asymmetries of information inherent in multiplayer and multigoal tradeoff problems, and they allow each participant to bring its own best information to the process to negotiate or create rules best suited for the situation.

The results of such arrangement-based programs are mixed. In some cases [e.g., the U.S. Environmental Protection Agency's (EPA's) Energy Star Program], they have achieved substantial benefits. In others cases, critics accuse regulatory agencies of becoming captured by their regulatory community. In general, the evidence suggests that these voluntary or negotiated programs work best in the following situations:

- **Benefits symmetry.** Compliance is in the best interest of all parties, and substantial gains can be demonstrated to be achieved by all major parties.
- **Threat of regulation.** Agreement on meaningful behavioral changes seems to occur when there is a real or perceived threat of a worse outcome from unilateral government regulation—the more realistic and draconian, the greater the willingness to compromise.
- **Mutually supported asymmetries of information.** When all parties have knowledge and information that will benefit the others (as is typically seen in complex technical problems where there is no single right answer and a number of about-right answers), agreement over goals and process occurs most likely in the form of a meaningful exchange of information.
- **Culture of cooperation.** Systems with a high degree of cooperation (or few large actors that dominate the regulatory community) promote voluntary rulemaking (e.g., there are more than 31,000 regulatory agreements in Japan and a far smaller number in the United States).
- **Preexisting behavioral codes or agreements.** Voluntary programs work best when they build on preexisting agreements (e.g., industry standards, professional ethics) that can then be codified or expanded.

Sustainability appears to have all these characteristics. In the future, it would seem that a greater move to sustainability in transportation may support and move to collaborative, negotiated, or voluntary rulemaking.

To date, the United States has been characterized by a general bias toward voluntary rulemaking for sustainability. For example, a benchmark survey of corporate sustainability programs identified nine major components: energy conservation, renewable energy purchases, Leadership in Energy and Environmental Design (LEED) building construction, greenhouse gas emissions, production and transportation, supply-chain accountability, product stewardship, solid-waste conservation, and water conservation (The Global Reporters, 2000). All this had been achieved despite the absence of a specific set of federal rules, regulations, or generally accepted guidelines that specify what practices or related requirements are sustainable.

Consensus on industry standards has long coexisted with regulations (and in some cases, it has been incorporated in regulations over time), and sustainability seems to be no exception. For example, the U.S. Green Building Council is conducting a pilot project to grant LEED credits for sustainability (including energy savings, water efficiency, and improved indoor environmental quality). Also, the American Society for Testing and Materials International (ASTM) released a compilation of Standards for Sustainability in Buildings (fourth edition), including the *Standard Guide for General Principles of Sustainability Relative to Buildings*, which describes methods of decisionmaking in applied sustainability (real-world sustainability involving cost–benefit tradeoffs). The ASTM standards have been incorporated into (1) the *Federal Green Construction Guide for Specifiers*, (2) the current public draft of the International Green Construction Code, and (3) the Green Globes sustainability rating system (Bennett, 2011).

This consensus on industry standards suggests that a more flexible sustainability regulatory system may be developing in the United States as a result of long-term culture change and the demands of customers and suppliers. The emergence of this model suggests that it is possible for sustainability systems to emerge from the current regulation process to create a more open, flexible regulatory policy.

2.3.8 Functions: Service and Product Delivery

Table 19 shows the evolution of service and product delivery from Safe Mobility to TBL Sustainability policy system models. Moving toward sustainability in service and product delivery involves embedding sustainability in every element of the service delivery, from sustainable procurement to service delivery. This means not only organizing transportation to support sustainable transportation and a sustainable society but also delivering transportation service in a sustainable manner. For example, the District of Columbia's Department of Transportation

Table 19. Service and product delivery under different policy system models.

Policy System Model	Characteristics
Level 0 Safe Mobility	• Efficiency and best value in all business processes • Transportation and mobility performance measured and reported
Level 1 Compliant Transportation	• Ad hoc sustainability initiatives • Efficiency and best value in all business processes—some environmental and social issues considered • Transportation and mobility performance measured and reported • Some environmental performance management reports
Level 2 Green Transportation	• Sustainability organizations established within agencies • Sustainability performance reporting and management
Level 3 Sustainable Transportation	• Sustainability embedded in all business processes (e.g., procurement, planning, design, construction, operations and maintenance) • Sustainability performance measured and reported for continual improvement
Level 4 TBL Sustainability	• Sustainability embedded in all business processes (e.g., procurement, operations and maintenance) • Sustainability performance measured and reported for continual improvement

sustainability plan incorporates and integrates sustainable practices throughout the department's work, ranging from office operations to construction and maintenance.

Paralleling the inclusion of sustainability into business practices, transportation agencies would need to develop a series of indicators to measure and manage sustainability. To date, this is where most agencies have focused their attention (Georgia Tech Research Corporation, 2011). In fact, states and local transportation agencies are in many ways the leaders in this area; thus, further progress will be able to build on a solid basis of achievement.

2.3.9 Functions: Compliance and Dispute Resolution

Table 20 shows the evolution of compliance and dispute resolution from Safe Mobility to TBL Sustainability policy system models. The compliance and dispute resolution process evolves slowly out of a highly politicized, conflicting system with a dependence on informal brokering of compromises between powerful stakeholders. As the process becomes more law based and compliance driven, informal brokering diminishes (but never quite disappears) and is replaced by more formal challenges via the courts. In many ways, this is the state of the current system when dissatisfied groups turn to litigation to slow down or reverse transportation issues that do not favor their interests. Policy systems under Sustainable Transportation and TBL Sustainability models would attempt to minimize these occurrences by involving the public in a participatory process and moving toward a deliberate-and-decide approach. The idea is to involve as many interests in decisionmaking as possible and allow them to compromise and take ownership of decisions, and thus avoid unresolved issues.

2.3.10 Functions: Internal Education, Training, and Culture Change

Table 21 shows the evolution of internal education, training, and culture change from Safe Mobility to TBL Sustainability policy system models. The critical elements in this process are to move away from an organization whose key function and self-perception is to provide transportation services to one that supports an overall sustainable society. This requires changing every element of a transportation agency's operation. A more diverse workforce must be developed that contains numerous different specialties, ranging from transportation engineers to ecologists, social scientists, communication experts, and community specialists. Extensive internal education and training needs to take place to educate staff on sustainability issues, practices, and processes. Furthermore, performance standards and promotion criteria need to be changed to reward

Table 20. Compliance and dispute resolution under different policy system models.

Policy System Model	Characteristics
Level 0 Safe Mobility	• Highly politicized • Informal brokering between powerful stakeholders
Level 1 Compliant Transportation	• Highly politicized • Informal brokering between powerful stakeholders • Dependence on law and courts
Level 2 Green Transportation	• Highly politicized • Dependence on law and courts
Level 3 Sustainable Transportation	• Politics are minimized • Emphasizes deliberate and decide • Avoids law and courts
Level 4 TBL Sustainability	• Politics are minimized • Emphasizes deliberate and decide • Avoids law and courts

Table 21. Internal education, training, and culture change compliance under different policy system models.

Policy System Model	Characteristics
Level 0 Safe Mobility	• Focus on technical specialties (transportation engineers) and standards • Performance standards and incentives associated with traditional performance measures
Level 1 Compliant Transportation	• Focus on technical specialties (transportation engineers) and standards • Performance standards and incentives associated with traditional performance measures
Level 2 Green Transportation	• Focus on multidisciplinary workforce—acceptance of flexible standards • Commitment to sustainability education, training, and internal incentives to be sustainable • Emerging culture of sustainability and stewardship
Level 3 Sustainable Transportation	• Focus on multidisciplinary workforce—acceptance of flexible standards • Commitment to sustainability education, training, and internal incentives to be sustainable • Culture of sustainability and stewardship
Level 4 TBL Sustainability	• Focus on multidisciplinary workforce—acceptance of flexible standards • Commitment to sustainability education, training, and internal incentives to be sustainable • Culture of sustainability and stewardship • Performance standards and incentives associated with sustainability

behavior that supports the sustainability mission of the agency. The overall aim is to develop a culture of sustainability and stewardship in which every individual understands the mission and is committed to achieving that goal in all aspects of his or her work.

2.3.11 Functions: Outreach and Communications

Table 22 shows the evolution of outreach and communications from Safe Mobility to TBL Sustainability policy system models. A great deal of the discussion on functional changes required to achieve a sustainable organization has focused on the importance of public outreach and communication. The key element that is useful to emphasize here is the importance of moving from one-way outreach (e.g., "This is what is going to happen") to more open two-way outreach (e.g., "What do you think? How can we better understand your needs?"). As a policy system moves from Safe Mobility to TBL Sustainability, it needs to develop an outreach system that encourages and incorporates citizens and affected parties into the decisionmaking and policy-making processes. This will build support for sustainability, ensure that policies address citizens' and affected parties' interests, and encourage people to use and gain the full benefit of sustainability-related investments.

Table 22. Outreach and communications under different policy system models.

Policy System Model	Characteristics
Level 0 Safe Mobility	One-way communication to explain transportation priorities and plans
Level 1 Compliant Transportation	One-way communication to explain transportation priorities and plans
Level 2 Green Transportation	Two-way communication to explain transportation priorities and plans and assess and incorporate feedback
Level 3 Sustainable Transportation	Two-way active engagement and communication between transportation agencies, the public, stakeholders, and decisionmakers
Level 4 TBL Sustainability	Two-way active engagement and communication between transportation agencies, the public, stakeholders, and decisionmakers

2.3.12 Summary of Policy Systems Models

The following series of diagrams (Figure 5 through Figure 9) summarizes the key elements of the policy system models described previously. The inputs, key characteristics of the policy community, key players (including regional planning organizations or RPOs, not previously mentioned), outputs, and feedback are identified. Note that, as the system moves toward sustainability, the feedback loops tend to reinforce and strengthen the trend toward sustainability.

2.4 Current Position of Transportation Agencies and Gap Analysis

Table 23 shows the current position of transportation agencies and other entities vis-à-vis the different policy system models identified and described previously. Additional follow-up tables at the end of this section summarize ratings for specific groups on different functions. Most states currently operate in a manner between the Compliant Transportation (Level 1) and the Green Transportation (Level 2) models. Specifically, many of the leading states have gone beyond strict processes and rules for compliance and moved into a more green system, where internal initiatives support sustainability practices; expanded participatory policymaking practices; and developed advanced sustainability indicator and planning systems. None has yet developed a Sustainable Transportation or true TBL Sustainability policy system. Similarly, federal

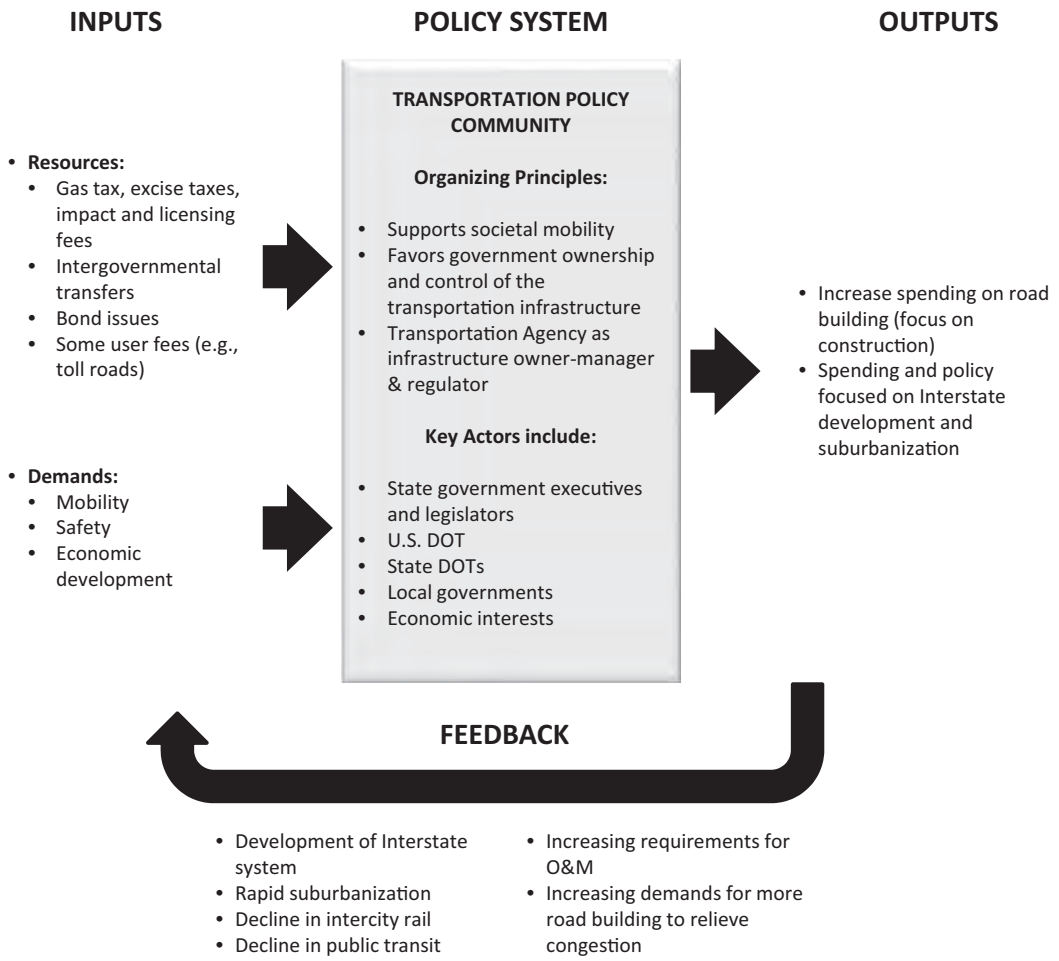


Figure 5. Safe Mobility (Level 0) policy system model.

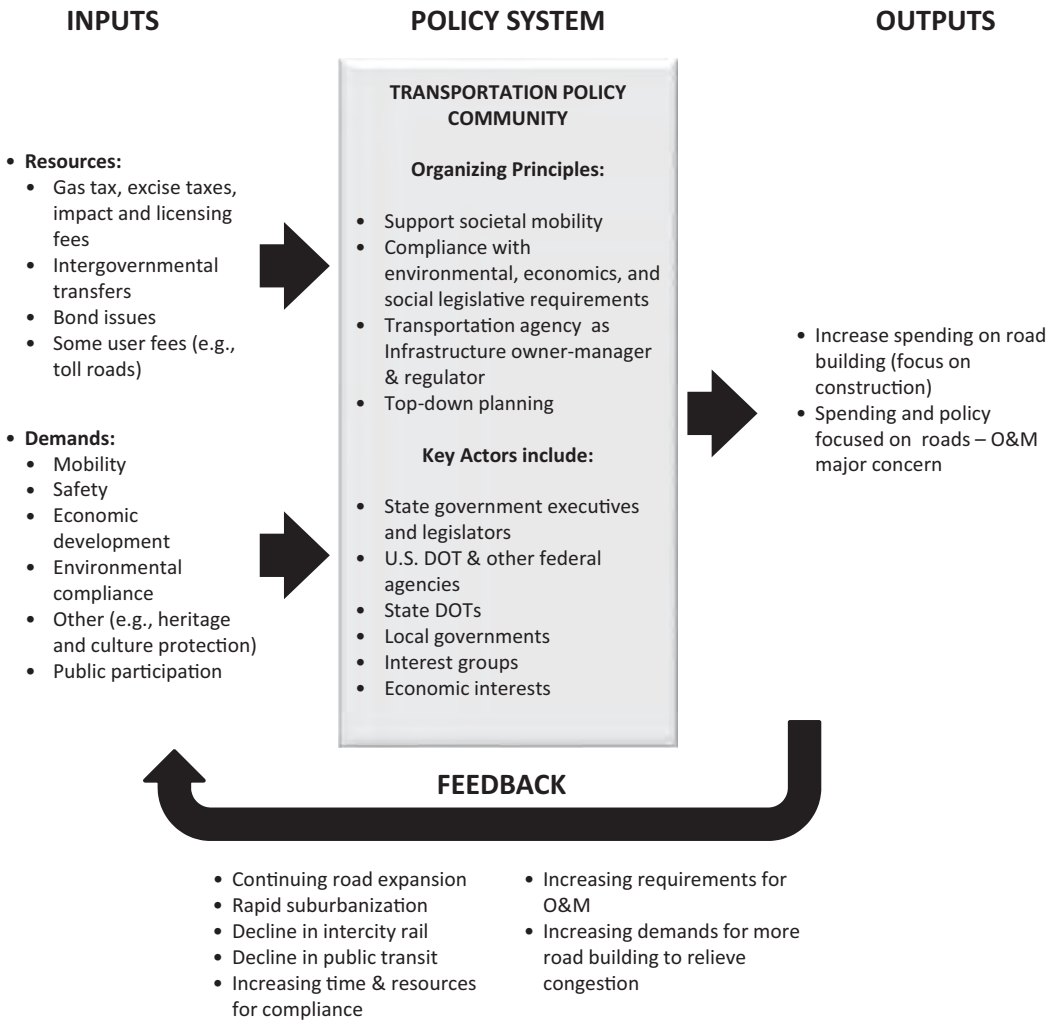


Figure 6. Compliant Transportation (Level 1) policy system model.

agencies are emphasizing compliance, internal standards, and performance metric development and culture change.

To date, Sustainable Transportation (Level 3) policy systems have been observed mainly at the local and international levels, with a few states exhibiting some characteristics of Level 3. This is for several reasons. First, localities and other major countries have great authority over land use and other issues that are critical to sustainable transportation. For example, the success of Portland, Oregon; Seattle; and Vancouver are partly because they have the ability to control land use via zoning and have authority over or are able to influence all modes of transportation in their jurisdiction. In contrast, most state transportation agencies control only the state highway system and have limited influence over other modal agencies and no control over land use.

Second, transportation is a regional or local issue inevitably. Its impacts are always keenly felt at a local level. Transportation problems, such as congestion, are felt first at a local level, and the pressure to respond to them is first attempted at the same level. States are generally larger and more diverse than the local levels. A transportation problem in one part of the state may not be experienced in another part of the state, and there will be little statewide political support to address this problem. Therefore, localities (and possibly smaller states with highly concentrated populations) are the first to address problems.

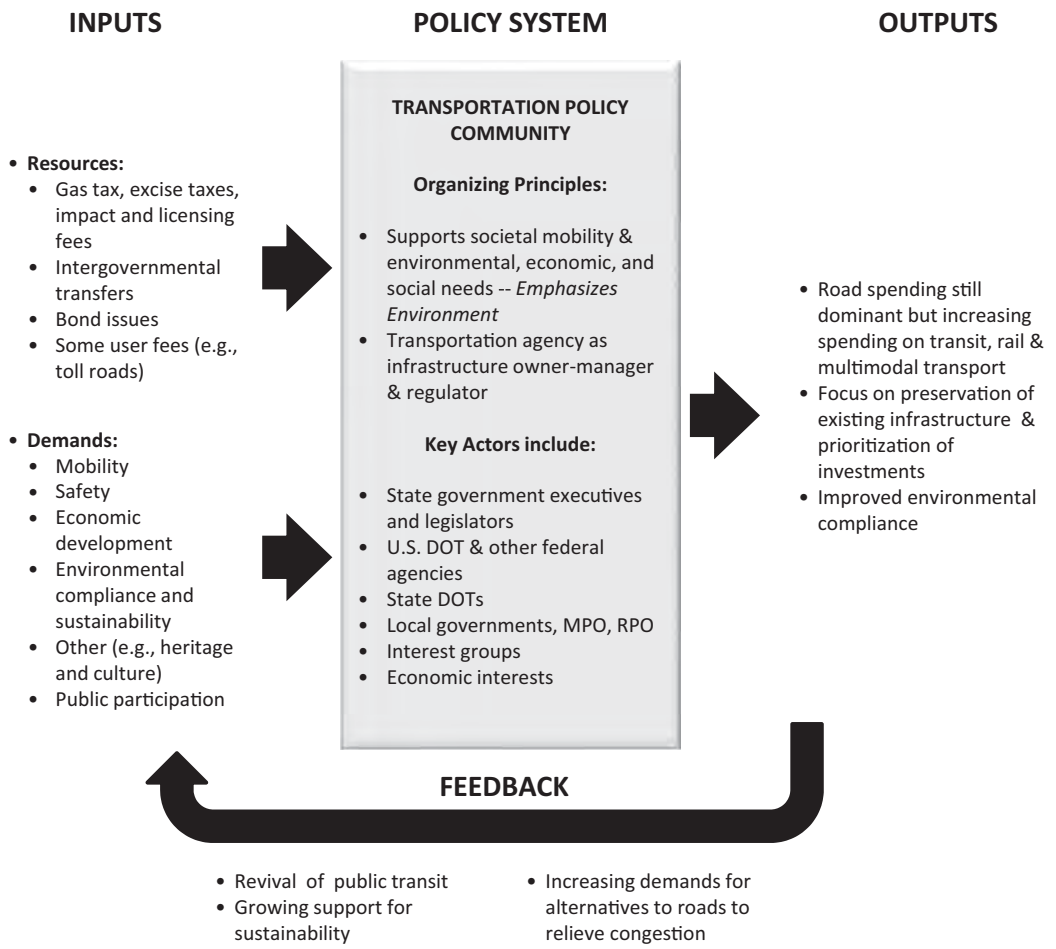


Figure 7. Green Transportation (Level 2) policy system model.

Third, localities often have more tools and options to generate revenues to support sustainability initiatives. Because of the previous two issues (local versus state government powers and concentrated versus distributed transportation problems), it is easier for local governments to develop a consensus around change, gain widespread support for the change, and then develop the local solutions (e.g., transit) to respond, than it is for more diverse states. Furthermore, as cities can build supportive coalitions from individuals that experience transportation problems directly, they are more likely to gain their support for bond issues, user fees, or increases in local taxes. For example, in Northern Virginia, special local districts were established in 2010 to levy a special tax on retail businesses to support the expansion of the Washington, D.C., metro system. This was after the state had failed to provide funds, because it was viewed as a project that benefited only one part of the state.

For all these reasons, cities and local governments are the leaders in sustainability. States, despite considerable progress, still lag behind. For them to catch up to cities, they would have to change a number of key factors. Critically, they would have to build a coalition within the state to support sustainable transportation. Local governments provide numerous examples of how this could be done; however, the proximity of the local governments to citizens makes it much easier for them to develop support. This suggests that one model for building sustainability at the state level may be to build sustainability from the ground up. For example, according to the interviews conducted for this project, southeast Florida's regional partnerships found themselves blocked by unresponsive leadership at the state level,

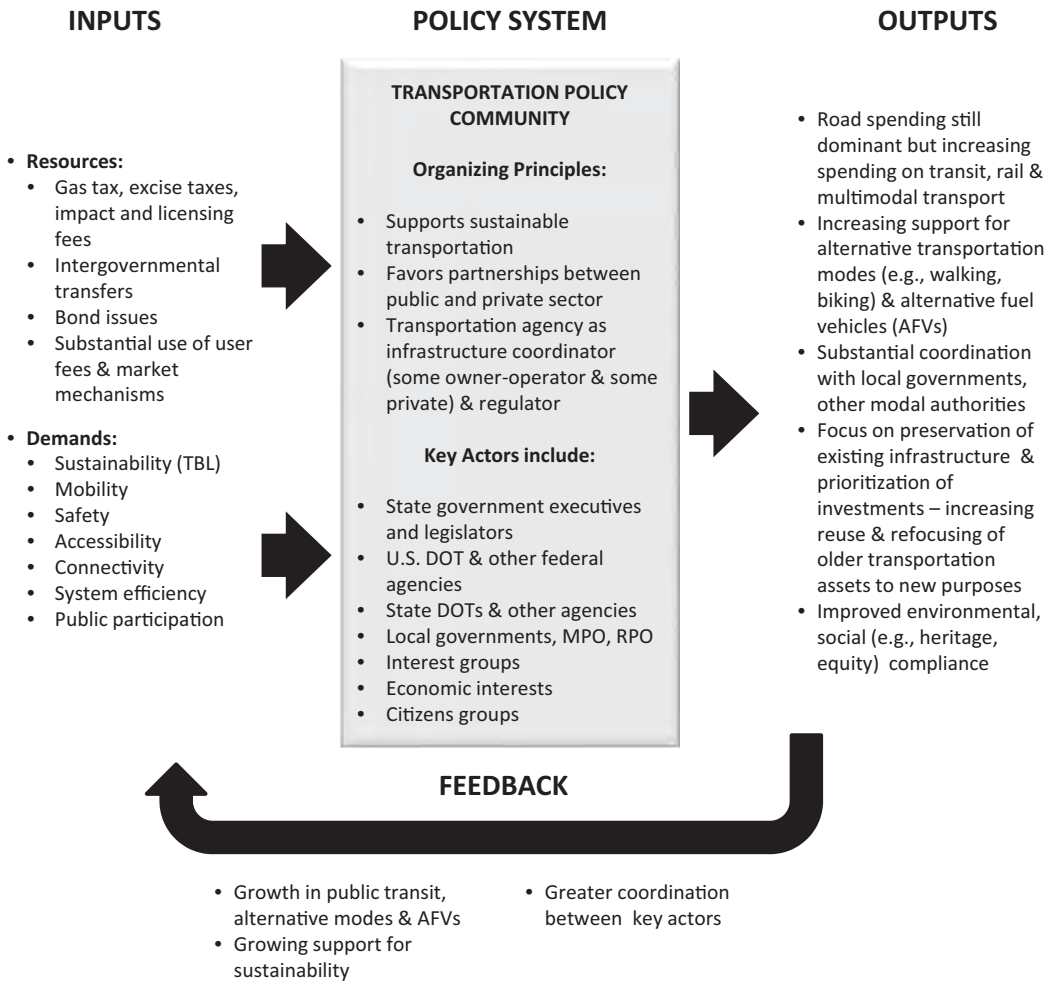


Figure 8. Sustainable Transportation (Level 3) policy system model.

and they began to develop coalitions to pursue their own transportation and sustainability initiatives. These islands of sustainability can expand gradually to include more communities and eventually reach a tipping point when sufficient political support has been built to change overall state policy.

Finally, the research suggests that cities and localities with strong growth economies are *more likely* to support comprehensive, advanced sustainability initiatives than localities with weak economies. The programs cited for leadership are predominantly connected with economically strong and growing cities, such as Portland, Seattle, Boulder, and New York. Other cities are more likely to focus scarce resources on specific bottom-line needs that can (or must) be met in the near term, and various public interest groups tend to focus more on specific needs at hand. Many improvements can be made for the transportation system to enhance long-term sustainability, but most transportation programs face significant funding constraints. Considering the competing goals that transportation agencies face today (e.g., mobility, safety, and fix-it-first) and the overall scarcity of funding, it is likely that, for a while, sustainability decisionmaking will be more focused on making choices and balancing priorities, and on compliance with regulations. For agencies currently experiencing major funding constraints and with a range of diverse needs within their jurisdictions, focus on long-term sustainability (in the TBL sense) can often take a back seat to more pressing issues.

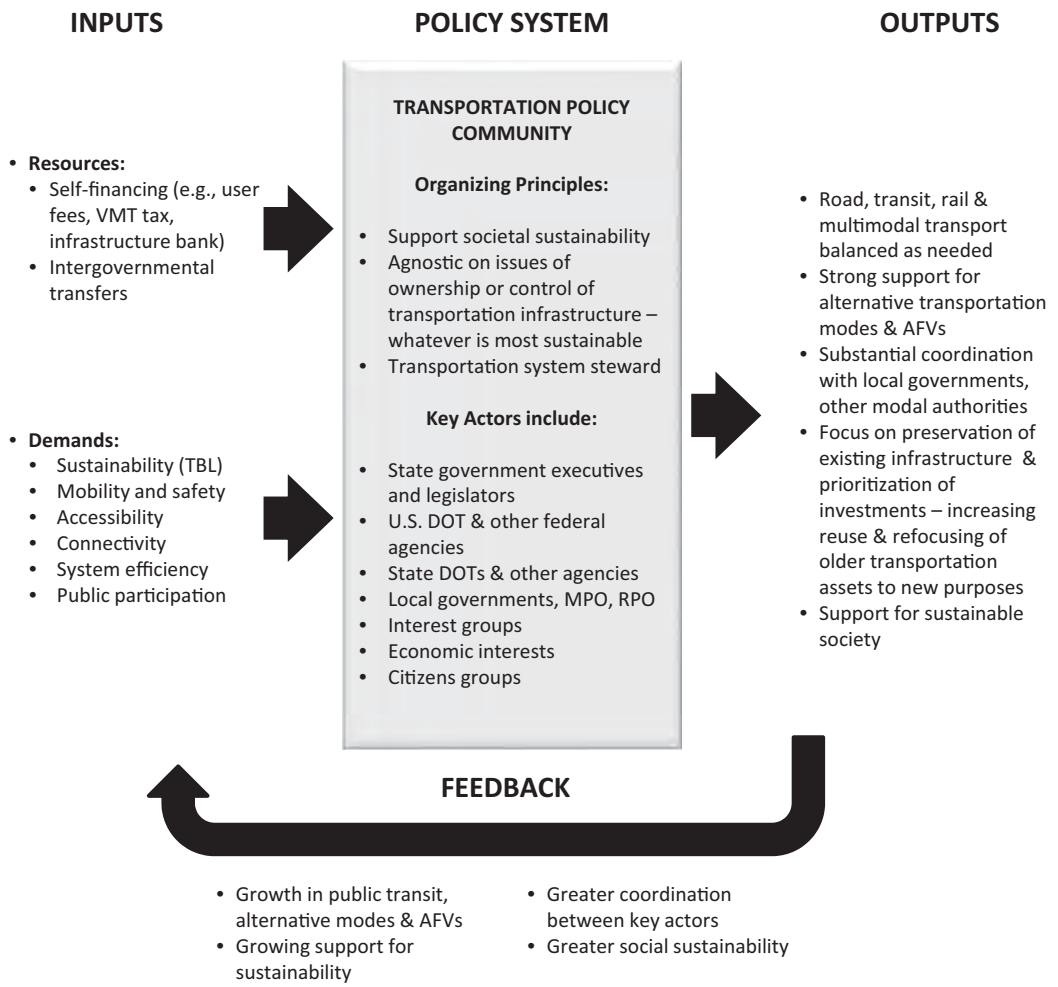
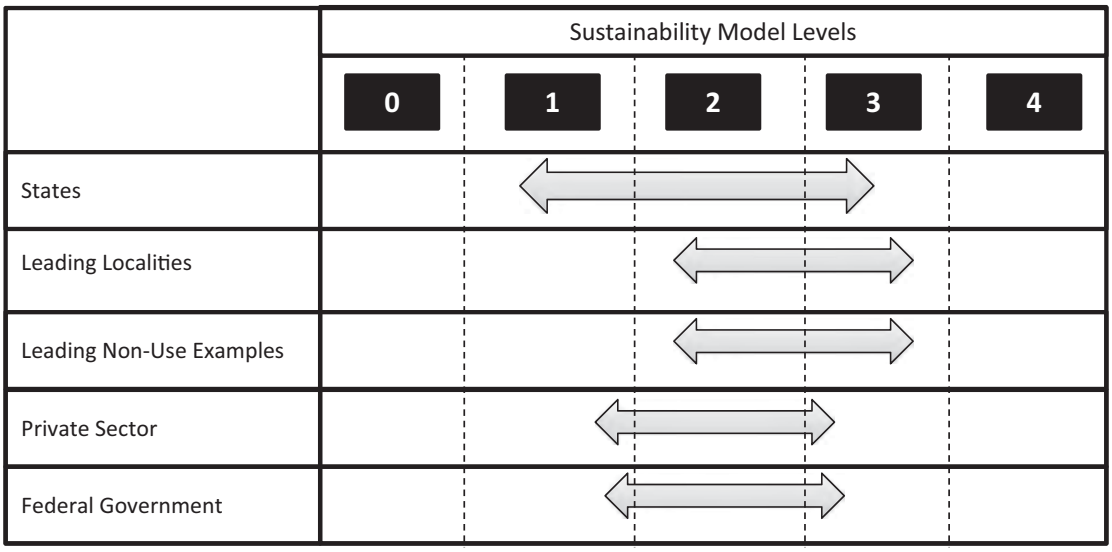


Figure 9. TBL Sustainability (Level 4) policy system model.

Table 23. Current position of different organizations and sectors vis-à-vis sustainability models.



In line with the definitions of TBL sustainability as serving long-term generational equity and values, cost of TBL requires assessment through a larger lens. A measure of *the total economic, social, and environmental capital gained or lost* is the best indicator of the cost *and* benefit of a given sustainability strategy. Under the TBL sustainability principle, if the balance between the bottom lines is optimized to address society's needs and priorities and the total capital for the three bottom lines is maintained as constant or increasing over a long period, then cost should not be an issue and generational equity is well served. So, it can be accepted that particular projects *might* incur increased short-term cost to incorporate sustainability objectives, but the long-term life-cycle cost can be lower, the local economy may benefit, environmental capital may be preserved, and social benefits can accrue. The question of whether a sustainability program or project is expensive depends not on upfront project-level cost but rather on the life-cycle cost and value of the plan.

The following chapters review how transportation might be able to support and advance beyond Sustainable Transportation policy systems to TBL Sustainability policy systems in the future.

CHAPTER 3

Scenario Development Methodology

3.1 Background

Transportation agencies face growing uncertainty. Changing state and federal budget priorities, potential major regulatory changes related to greenhouse gas (GHG) emissions, and major technology changes (e.g., connected vehicles, high-speed rail) mean that state transportation executives are increasingly uncertain about the future (AASHTO, 2010). In particular, these issues are likely to affect the organizational principles around which state transportation agencies are established.

These challenges are even greater when long-term perspectives are required from transportation decisionmakers, such as that necessitated by a commitment to sustainability (i.e., sustainability requires that decisionmakers consider the impact of their transportation decisions on future generations' ability to support and sustain their society). Specifically, shifting demographics, disruptive technologies, major statutory and regulatory changes, increasing environmental stress, and uncertainty about the future distribution and rate of economic growth all mean that traditional organizations will be challenged to find new operating principles (Friedman, G., 2010, 2011; Friedman, T. L., 2007, 2009). Traditional input-output planning models have been of little value in helping agencies navigate environments characterized by a high degree of uncertainty (Shoemaker, 1995, 1997; Shoemaker and Gunther, 2002; van der Heijden, 2005; Schwartz, 1991). Instead, scenario planning has emerged as a means to help analysts and decisionmakers envision the different requirements that organizations will have to address in the radically different future conditions (often referred to as *future worlds*) (AASHTO, 2010).

Scenario planning helps organizations look into the future and anticipate events and trends, understand risk, provide ideas for preemptive organizational response, and help managers break out of their established mental models as they become aware of alternative future possibilities. A scenario is a set of related possibilities that describe one possible future that the strategist cannot control. Although there is no consensus on the definition or approach to scenario planning, typically, a scenario is a rich narrative or story describing a possible outcome (Schwartz, 1991). Despite the difficulties in defining scenarios or developing a single approach to scenario development, there is a clear consensus that scenarios are not predictions (van der Heijden, 2005). Instead, "Scenarios are consistent and coherent descriptions of alternative hypothetical futures that reflect different perspectives on past, present, and future developments which can serve as a basis for action" (van Notten, 2005).

Scenario planning has a long history, dating back to its roots in 19th century military operational planning. In the 20th century, interest in scenario planning reemerged in the work of the RAND Corporation and the writings of Herman Kahn (Kaplan, 1991). Essentially, Kahn's approach was to develop three basic scenarios: (1) the most likely (or baseline) case scenario, (2) a worst-case

scenario, and (3) a best-case scenario. By the 1960s, the scenario-planning approach was moving beyond the worst-case/most likely–case/best-case paradigm to consider more open-ended alternative futures in large part because, while the simple, linear, single-dimension approach to scenario development was well suited to military planning (where, originally, outcomes were anticipated to occur as a single event, with a single, logical, short-term and long-term chain emerging from that event), it was hopelessly limited when facing the ambiguous and open-ended environment of government and business (Michel and Roubelat, 1996, 2000).

General Electric and Royal Dutch Shell pioneered an alternative approach to scenario planning that was based on the development of a number of different future worlds that were neither good nor bad, but possible. The goal of this approach to scenario planning was to sensitize management and planning staff to alternative planning assumptions (Diffenbach, 1983). In particular, Royal Dutch Shell's Group Planning Department, led by Pierre Wack, explored the environment for events that might affect the price of oil. The team identified several issues, including the steady exhaustion of U.S. oil reserves and the expanding role of the Organization of Petroleum Exporting Countries (OPEC; which might demand higher prices for oil), and developed full scenarios for two cases: (1) steady oil prices and (2) massive oil crisis triggered by OPEC. In October 1974, the second scenario was realized, and Shell was the only major oil company able to respond. Shell's adept response enabled the firm to move from seventh to first in profitability in the industry (Cornelius et al., 2005).

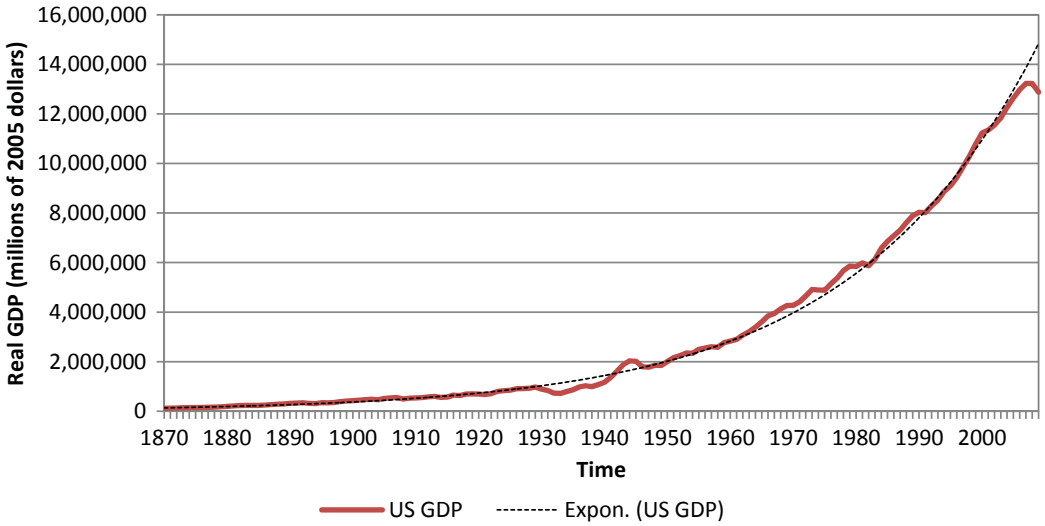
The perceived success of the Shell experience led to a sudden increase in the use of scenario planning and an enormous proliferation in scenario-planning approaches and goals. Policy theorist Philip Van Notten conducted a detailed analysis of the use of scenario planning in government, industry, and the private sector and developed a typology that described the range of goals and methodologies. This typology used three broad macro characteristics and nine micro characteristics.

Macro characteristics addressed the why, how, and what of a scenario exercise (i.e., its goals, the process design, and the scenario contents); *micro characteristics* described the specific goals, participants, methodologies, and analytical techniques used to build these scenarios, such as the following (van Notten, 2000):

- Function of the scenario exercise
- Role of values in the scenario process
- Subject area and issues covered
- Nature of change addressed (discontinuity versus evolutionary)
- Nature of the inputs into the scenario process
- Methods used in the scenario process
- Degree of group participation versus model-based analysis
- Role of time in the scenario
- Level of integration of different scenario elements

The result of this analysis is that there is no firm consensus concerning the correct approach to scenario analysis and that the methods are highly context dependent. Thus, the use of specific techniques (e.g., the use of "wild card"—high-impact, low-probability—events) in scenario-planning exercises is best in (1) tabletop or wargaming/strategic simulation exercises, where decisionmakers explore how their plans and assumptions might be disrupted by unexpected, high-impact events, or (2) crisis-prone systems, where sudden radical discontinuities can change long-held assumptions and methods of doing business (Rockfellow, 1994; Petersen, 1999).

In longer-term, society-wide scenario analysis, individual events are less likely to have major long-term effects due to the relative strength of macro-level trends. For example, despite numerous policy changes and major historical and social events, U.S. gross domestic product (GDP) has



Source: Johnston and Williamson (2011).

Figure 10. Real U.S. GDP growth, 1870–2009.

shown a remarkable stable upward pattern that can be modeled easily as an exponential trend (see Figure 10).

Furthermore, when the entire period is considered, a remarkably stable growth pattern emerges. In fact, when the entire period from 1870 to 2009 is considered, despite numerous wild cards (e.g., wars, economic fluctuations, policy changes), U.S. real GDP grew at an annual rate of approximately 3 percent.

From a scenario-planning perspective, the power of long-term trends suggests that many events are over-determined (i.e., there are many drivers that are shaping long-term changes) and that the power of any one event or wild card to affect long-term change is vastly overrated [for more discussion of this point, see Thompson (1978)]. This does not mean that individuals or events cannot change the direction of the future; it simply means that their power to disrupt decades-old forces and trends that are the combination of millions of individuals' single acts is limited and that these events or individuals rarely have truly long-term consequences. While such paradigm shifts do occur (e.g., the shift from rail to car), they are often the result of numerous long-term forces acting on each other (e.g., technology, economic development, national policy shifts, and millions of individual decisions led to the adoption of the automobile).

Paradigm shifts that occur separate from these long-term trends are difficult to identify and, for purposes of this phase of the project (i.e., identification of requirements in the shape of challenges and opportunities for Phase II), are of limited value. Thus, for longer-term, macro scenario building, an approach that focuses on long-term, powerful social, economic, technological, and geographical factors is more appropriate than considering shorter-term events. Specifically, this approach is more likely to capture the main forces to which individual organizations (such as state DOTs) will have to respond over several decades rather than the day-to-day, year-to-year events that may distract organizational planners from important long-term changes.

This approach is consistent with the FHWA scenario-based planning methodology. The FHWA approach involves six general steps and is a dynamic methodology, allowing transportation planners to generate new scenarios as events occur (see Section 3.2). The first step in the FHWA process is to identify driving forces, or macro-level trends. Driving forces are "the major sources of change that impact the future" (FHWA, 2010). Commonly used driving forces include local

land use, levels of congestion, and local demographics. The second step is to determine patterns of interactions. Patterns of interactions between driving forces can be determined in a variety of ways. The FHWA recommends that transportation planners use a matrix and develop a metric related to positive or negative outcomes. The third step involves creating scenarios from these matrices by fitting realistic situations to predicted patterns between the driving forces. The FHWA describes the goal of creating scenarios as bringing life to possible alternatives in a way that community stakeholders can easily recognize and connect the various components. The fourth step is to analyze the implications of the scenario. In this step, transportation planners and stakeholders develop potential transportation policies that mesh with the scenarios. Evaluating scenarios is the fifth step in the FHWA's methodology. The FHWA describes a variety of methods for evaluating scenarios, such as using various criteria and presenting the scenarios to community stakeholders (e.g., through a decision-analysis session or individual interviews). The sixth and last step is monitoring relevant indicators of the scenario.

3.2 Scenario Development Methodology

Figure 11 provides an overview of the research team's approach. The project began with a meeting with the NCHRP 20-83(7) panel to agree on key assumptions, strawman drivers that could affect organizing principles, and the scope of the project. Based on this meeting, the research team conducted an in-depth scan of the current futurist literature, conducted interviews with subject matter experts (SMEs), held internal SME discussions and panels, and identified a series of drivers that will affect the long-term development of U.S. society and thus affect state transportation agencies' organizing principles.

Table 24 presents the drivers identified using the research team's approach; Appendix A describes each driver in detail. For each driver, the research team established a series of alternative outcomes or stories that describe how that driver might evolve or change between 2010 and 2050. Detailed descriptions of each driver, the data and methodology used to develop driver outcomes, and additional supporting information can be found in Appendix A.

The research team then used a scenario-building technique known as "morphological analysis" (Zwicky, 1969; Zwicky and Wilson, 1967). General morphological analysis was developed as a method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable problems (Ritchey, 2006). Traditional scenario planning emerged as an alternative to formal (mathematical) methods and causal modeling as a form of non-quantified modeling that relied on *judgmental processes* and *internal consistency* rather than on causality. However, scenario planning did not provide any guidelines as to how to place the non-quantifiable dimensions of scenario development on a sound methodological basis.

Morphological analysis offers a solution to this problem by extending the traditional scenario-planning techniques through a *cross-consistency assessment* (CCA) approach. CCA is a method for rigorously structuring and investigating the internal properties of inherently non-quantifiable problem complexes, which contain any number of disparate parameters. It encourages the investigation of boundary conditions and virtually compels practitioners to examine numbers of contrasting configurations and policy solutions.

Essentially, general morphological analysis is a method for identifying and investigating the total set of possible relationships or configurations contained in a given problem complex. In this sense, it is closely related to typology construction, although it is more generalized in form and

Role of Projections

For many drivers that lent themselves to quantitative treatment (e.g., population), the research team used a variety of projections to express different trends that are identified by experts. The research team included more qualitative judgments, where appropriate, in the development of the overall scenarios.

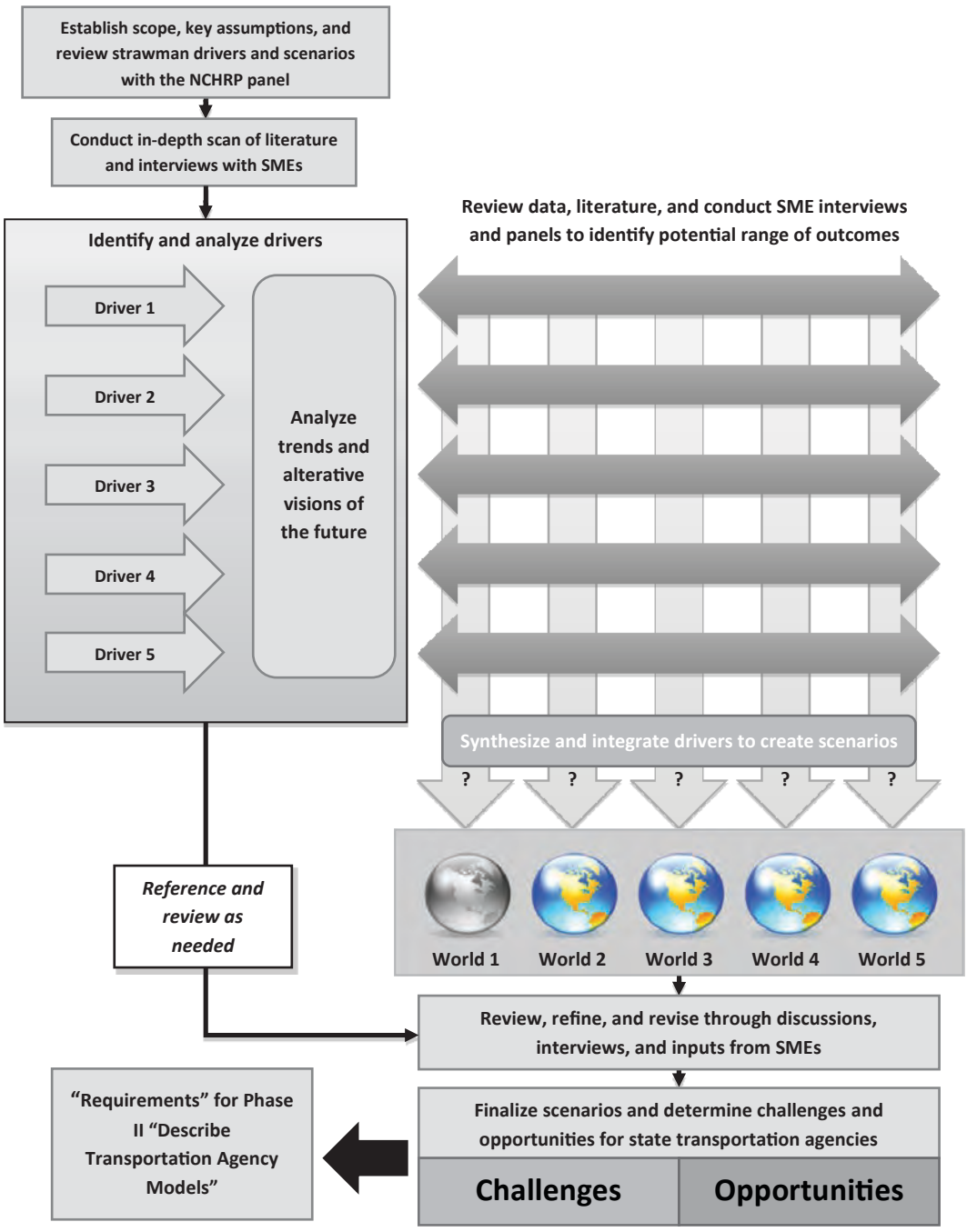


Figure 11. Overview of the scenario development approach.

conceptual range. The approach begins by identifying and defining the parameters (or dimensions) of the problem complex to be investigated and assigning each parameter a range of relevant values or conditions. A morphological box (also known as a Zwicky box) is constructed by setting the parameters against each other in an *n*-dimensional matrix. Each cell of the *n*-dimensional box contains one specific value or condition from *each* of the parameters and thus marks out a specific state or configuration of the problem complex.

For example, imagine a *simple problem complex*, defined as consisting of three parameters or dimensions (e.g., color, texture, and size). Further, assume that the first two dimensions

Table 24. Scenario drivers affecting organizing principles*.

Scenario Driver	Definition	Impact on State Transportation Agencies and Organizational Principles
Demographic Factors	The size, distribution, and characteristics (e.g., age, sex, ethnicity) of the U.S. population	This driver will affect organizing principles by helping to determine travel demand and, indirectly, the resources that are available to transportation agencies.
Economic Growth and Public-Sector Spending on Transportation	Future patterns of economic growth (e.g., GDP, inflation, investment, employment, income growth) and public-sector spending (e.g., federal, state, and local) on transportation	This driver will affect organizing principles by determining the resources that are available for transportation agencies and the level of transportation demand (as generated by economic activity).
Energy (Includes Transportation Energy Uses and Fuel Prices)	Future changes in energy use and the proportion of energy derived from different sources; Includes the price and fuel sources used, by modes of transportation	This driver will affect organizing principles by helping to determine travel demand (e.g., via fuel prices and energy availability).
Climate Change, Environment, and Resource Use	Future changes in the environment (in particular, climate change), resource availability, and resource use	This driver will affect organizing principles through impacts on environmental resource shocks, travel demand, and state-specific environmental challenges that transportation agencies will face.
Transportation Technology	The development of future transportation technologies and the degree to which these technologies are adopted by individuals and networks	This driver will affect organizing principles by determining the transportation options available, travel demand, requirements for investment and capital decisions in the future, and the choices that need to be made.
Land Use	Population distribution, demographics, land use patterns, and development factors	This driver will affect organizing principles through travel demands and the requirements for state transportation agencies.
Future Transportation System Funding, Operation, and Control	Funding, degree of shared ownership with the private sector, and centralization/decentralization (i.e., the roles of federal, state, regional, and local governments)	This driver will affect organizing principles via the resources they have; challenges and opportunities caused by shared ownership; and the role of federal, state, regional, and local governments.

*Detailed descriptions of each driver, the data and methodology used to develop driver outcomes, and additional supporting information can be found in Appendix A.

consist of five discrete values or conditions each (e.g., color = red, green, blue, yellow, brown) and the third consists of three values (size = large, medium, small). Then there are 75 (= 5 × 5 × 3) cells in the Zwicky box, each containing three conditions—one from each dimension (e.g., red, rough, large). The entire three-dimensional matrix is a morphological field that contains all of the (formally) possible relationships involved. For this study, the research team identified several different drivers and identified the range of potential values that each driver could take on. The team then considered each potential combination of drivers. Those that did not make logical sense were excluded from further analysis. Those that were included were expanded to form full-scenario descriptions for further analysis.

Using this approach, the research team developed a series of scenarios that expressed a number of alternative worlds for 2050. The NCHRP panel then reviewed and slightly modified the general

descriptions of the scenarios. Based on the panel's comments, the research team conducted detailed research to fill out the scenarios, held interviews with SMEs and futurists, and developed detailed descriptions of the scenarios. Booz Allen SMEs then reviewed these scenarios in an all-day session to validate and review assumptions. These SMEs included transportation planners and experts, transportation technology experts, environmental experts, economists, and individuals who formerly had been state and local transportation officials before joining Booz Allen. These SMEs were supplemented with several academics external to Booz Allen to rule out the potential for organizational biases. Based on their comments, the research team again revised the scenarios and submitted a draft report describing them to the NCHRP panel. The panel made additional comments, and the research team revised the scenarios to reflect the consensus of the future. These finalized scenarios formed the basis for identifying the challenges and opportunities that different types of state transportation agencies could face in the next 40 years.

CHAPTER 4

Description of Scenarios

Using the approach described in the previous chapter, the research team developed five scenarios: Crisis World, Mega World, Suburban World, Wonder World, and Green World. In developing these scenarios, the research team made the following **key assumptions** with the identified **caveats and limitations**:

- All scenarios assume that there will be no major international war involving the United States, social or economic collapse, or technological singularity [i.e., extremely rapid convergence of technologies leading to a huge acceleration of technological progress and economic growth; for a full description of what is envisioned under a "singularity" scenario, see Garrean (2005) and Kurtzweil (2005)].
- All scenarios include some reference to major economic and social trends (e.g., population, economy) and follow anticipated trends with minor variations. In these cases, the research team used simple projections to portray the future direction of events. The scenarios vary from each other by using other drivers, including environmental change, fuel prices, social/cultural choices, market and individual responses, and technological change.
- Scenarios are not simply driven by technology. Technology will play an important part in the future of the U.S. transportation system, but many factors will affect the rate of technology adoption and how current and future technologies are integrated into future transportation systems. As a result, the research team included low-adoption and high-adoption technology scenarios.
- No single scenario will happen everywhere across the country in the same way. There will always be variations and differences—some areas, even in the most negative scenarios, will experience extremely positive futures; some areas in positive scenarios will experience extremely negative futures.
- Scenarios should reflect a variety of different situations that are sufficiently dissimilar to be able to show meaningful variances. As a result, the research team includes a less-than-credible scenario (i.e., Crisis World) to contrast the different potential outcomes.
- Scenarios focus on implications for transportation systems, organizing principles for state DOTs, and challenges and opportunities for state transportation agencies.
- Scenarios emphasize challenges and opportunities to all dimensions of sustainability—environmental, economic, and social/cultural.
- Scenarios are not intended to make political assumptions or policy recommendations. These descriptions attempt only to convey plausible business environments for transportation agencies.

In terms of negative scenarios, the research team developed a very negative scenario, Crisis World, in which slow economic growth, rapid environmental degradation, and slow technology improvement combine to create a world where the United States faces a series of crises that place considerable stress on the transportation system and the ability of state transportation agencies to meet basic transportation needs.

The research team developed two mid-range scenarios: Mega World and Suburban World. Mega World is essentially a continuation of current trends. Population and the economy grow as anticipated by most mainstream analysts, and technology improves in a predictable manner. Environmental change and resource use are manageable, and there are gradual manageable improvements in environmental conditions and resource use. The main difference between this scenario and the other mid-range scenario, Suburban World, is that population becomes increasingly concentrated in megaregions, creating major problems for governance and intergovernmental coordination.

Suburban World is identical to Mega World in every respect except for the distribution of population. Under Suburban World, technological and sociocultural changes allow the population to become more evenly distributed. Small towns and mid-range cities grow, and suburban and exurban areas around cities continue to grow. As a result, there is a rural renaissance during which the United States comes to resemble the early 20th century in terms of population distribution.

The research team identified two positive scenarios: Wonder World and Green World. In Wonder World, technological change is rapid and produces dramatic economic growth. The United States remains a dynamic, fast-growing country with a diverse, youthful population from immigration. Environmental stressors are minor and are easily dealt with by technology and abundant resources. The major challenge that state transportation agencies face is keeping up with technological change and managing the transitions to new forms of mobility.

In Green World, there is a fundamental reorganization of society toward a more sustainable and environmentally benign form of operation. Spurred by new green technology, the economy grows rapidly while dramatically reducing environmental and resource stressors. Population is decentralized into relatively small communities and highly centralized urban cores. State transportation agencies face considerable challenges in transitioning the existing transportation systems to a more sustainable system but are assisted by a public that eagerly supports the greening of infrastructure.

In the following sections, the research team summarizes key drivers for each scenario and provides scenario stories that dramatize the situations, providing background and helping readers grasp the world and the opportunities and challenges for state transportation agencies. As noted previously, for more detail on the drivers and the assumptions used to develop these scenarios, see Appendix A.

4.1 Crisis World

Crisis World, the most pessimistic scenario the research team developed, is a world undergoing a persistent, recurrent, multidimensional crisis (see Table 25). Under this scenario, environmental crises and resource depletion are occurring much sooner and more quickly than currently anticipated, while the United States is trapped in an unrelenting, ongoing economic recession where growth rarely rises above 2 percent. As a result, the United States is under considerable stress and lacks the resources to respond to the challenges it encounters. The stresses and strains of the Crisis World scenario lead people to begin to change how they live and to move to more sustainable ways of living in response to environmental and economic crises and rapidly increasing resource prices. In the public sphere, these trends and the seriousness of these problems lead to a new public commitment toward sustainability and toward creating transportation systems that support a sustainable society.

Table 25. Scenario drivers—Crisis World.

Driver*	Description
Population	• Low economic growth and recurrent crisis leads to slow population growth—399 million.
Economic Growth	• From 2020, GDP falls by 8% over the next 30 years under the low-growth projected case. • Spending on transportation for federal, state, and local governments stays at the historic average of just under 2% of GDP.
Climate Change, Environment, and Resource Use	• Dramatic, worse-than-expected climate change occurs—multiple acute† events (e.g., floods, heat waves, worsening hurricanes, and storm surges). • Major resource shortages—gas prices are in excess of $9/gallon for long periods with huge fluctuations in price. • Petroleum and other carbon fuel remain important sources of energy.
Transportation	• Transportation technology does not deliver—no major breakthroughs; new transportation technologies remain too costly for widespread adoption. • MPO and megaregional organization dominate transportation planning and management. • Federal government highly involved in emergency resources.
Land Use and Distribution of Population	• Population concentrated in megaregions. • Mix of megacities and suburban sprawl continue.

* For the tables in this section, several drivers have been collapsed into a smaller number of drivers [e.g., "transportation" includes transportation technology (vehicles and infrastructure) and potential organization of transportation agencies] in order to facilitate discussion.

† An "acute event" is a sudden, unplanned, negative event that can cause serious harm to human health; the environment; economic resources; or items of historical, cultural, or social value.

Scenario Story—How the World Might Change: Crisis World

After the financial crisis of 2008, the initial optimism for a 2012–2013 recovery stalls. The U.S. economy fails to recover to its previous dynamism. As analysts debate the causes of the so-called "Long Recession of 2010 to 2050," debt overhangs, long-term structural deficits, dramatic increases in resource prices, and a collapse in global demand all contribute to the depth and magnitude of the recession. Oil is not the only resource to approach peak output; minerals such as copper, magnesium, iron, and rare-earth minerals vital for modern life also experience rapid price increases. In addition, energy-intensive fertilization and mono-crop cultivation lead to rapid depletion of topsoils, while energy prices make extensive irrigation cost prohibitive. Throughout the entire period, economic growth barely reaches 2 percent, leading to persistent, long-term unemployment and a collapse of living standards in many areas. One result is that state and local governments lack the resources to address the growing challenges they face and are forced to rely on the increasingly overburdened federal government for relief.

Conditions worsen substantially due to growing indicators of rapid global change. The Great Storms of 2018 hit numerous U.S. coastal cities along the Gulf of Mexico and the Atlantic Coast, leading to major disasters that overwhelm the ability of state and local governments to respond and causing major damage to private property and infrastructure. Early melts of snow packs and winter rains lead to floods throughout the West and Midwest on a recurrent basis. At the same time, long droughts in the Central Plains lead to declining yields, a collapse in agriculture in the Southern High Plains, and a decline of many cities in drought areas. More rapid exhaustion of the Ogallala Aquifer, combined with increasing fuel prices to operate irrigation systems, leads to a return to dry land farming in southern Kansas, Oklahoma, and Texas, while the increasing number of wind-storms and the higher wind speeds cause soil loss in agricultural areas and reduce soil moisture.

The Pacific Northwest, already dealing with the onset of new climatic patterns and severe storms, also experience climate refugees as the economy of the Southwest and southern California

collapse, leading to mass migrations. Arizona, southern California, Nevada, New Mexico, and Utah all face major water shortages during record heat waves, major wildfires, and dust storms [see Morello (2010)]. By 2040, global temperature has increased, leading to periods of dramatic temperature instability and the first clear indicators of the collapse of the Greenland Ice Shelf.

Simultaneously, the United States and other Northern Hemisphere countries experience a dramatic rise in sea level, leading to flooding of major coastal cities and the loss of significant coastal infrastructure (e.g., subways, rails, sewer systems, bridges, roads, ports, and shipping systems). In response, skyrocketing insurance and reinsurance costs further retard economic growth, creating more economic turmoil and increasing business and consumer costs. Even for those areas not affected by sea-level rise, increasing fuel prices make it cost prohibitive to heat homes and work in the long, deeper winters. The more intense storm season stresses the abilities of many families and communities to maintain their standard of living and hopes for a better life.

In terms of transportation technology, the hopes of the early part of the 21st century do not materialize. Slow economic growth and a lack of public investment in new technologies mean that only relatively wealthy communities adopt the technologies and only a few individuals adopt new automobile technologies. Furthermore, increases in the price of rare-earth elements and an embargo of rare-earth elements in 2040 end substantial investment in electric-vehicle technologies [for more on the issue of rare-earth elements and the U.S. dependence on foreign oil, see Ngai (2010)]. As a result, despite rising petroleum prices, Americans remain committed to their automobiles and a carbon-based economy.

In terms of transportation, the increase in petroleum prices (rising to more than $9 per gallon in 2010 dollars with massive fluctuations) makes private automobiles a thing of the past. Families move closer to cities to avoid the increasing costs of mobility. Commuting costs increase dramatically, deeply affecting home values in all areas and creating more economic problems. Increased transportation costs for almost all goods lead to spiraling price increases, the end of just-in-time delivery-and-distribution systems, and further declines in global trade. Long-distance travel of personal vehicles on interstate highways is beyond the reach of most individuals, increasingly being reserved for freight. Increases in fuel costs mean that air transportation is available only for the very rich. Most people travel by train or bus when they have to travel between cities.

In terms of institutional and governance issues, political paralysis in the face of massive, long-term, structural federal deficits severely limits the federal government's freedom and ability to act and help state and local governments. Low growth, combined with uncontrolled federal spending, leads to massive deficits and a crowding out of the private sector from the capital markets. Even without the additional spending caused by emergencies related to climate change, the federal deficit would reach staggering levels of more than 340 percent of GDP by 2050 (U. S. Congressional Budget Office, 2010). With the additional spending on new seawalls, flood barriers, and relocation of infrastructure, deficits become ever higher. As a result, the federal government increasingly withdraws from its transportation and many other responsibilities and increasingly focuses on the national crisis.

The transportation infrastructure falls into rapid decline as state and local governments make hard choices to prioritize only the surface transportation systems required for commerce and economic viability. In many areas, there is ad hoc, unplanned privatization, as state and local governments shift assets to the private sector in an effort to reduce operations and maintenance (O&M) costs and focus on essential assets.

Within urban areas, state and local governments are increasingly unable to maintain infrastructure. Bridge closures, poorly maintained roads and highways, and failing public transit systems increase congestion to record levels, leading to reduced demand in many cities. Without federal support, states and localities accelerate the move toward self-financing policies.

However, after promising starts, rapid increases in the price of fuel lead to public protests against congestion pricing, which in turn lead to a general rollback in congestion pricing and even to the reduction or abolition of the gas tax in some states. As a result, only a few cities are able to retain congestion-pricing policies.

As the period progresses, there is a general move toward uncontrolled privatization, with many wealthy individuals buying their way out of congestion by using private roads. By 2030, it is not uncommon for transportation assets in wealthier areas of cities and suburbs to be owned entirely by local homeowners associations, with their operation contracted out to private surface transportation management companies. In other parts of cities and in poorer suburbs (where lower-income families are increasingly found), there are fewer and fewer transportation options as state and local transportation agencies increasingly focus on providing only crucial transportation links. As with the privatized system, state and local governments contract out operations to privatized transportation O&M, focusing instead on planning, decisionmaking, and oversight.

At the same time in rural areas, the ongoing recession and the collapse of local revenue bases lead to the collapse of rural infrastructure and further economic decline. As a result, transportation systems in many rural areas collapse to almost pre-industrial levels or shift responsibility to a mix of local transportation companies, transportation cooperatives, or single individuals or companies that are prepared to take over O&M of surface transportation systems.

The situation is worsened by the U.S. population's rapid aging. The declines in immigration mean that the U.S. population is considerably older but without the benefits of younger immigrants to help support that aging population. The increasing dependency ratio means that individuals are working longer as social security and long-term medical-care benefits are cut to deal with more immediate needs. Older Americans increasingly work from home and rely on ride shares and shared drivers to meet their transportation needs.

However, there are signs of hope. The Internet (for telecommuting, entertainment, delivery efficiencies, coordination of commuting, shopping, and more) becomes more important. Although cheap consumer goods and the consumer society are things of the past, increasing energy costs mean an end of outsourcing and energy-intensive farming. Local operations similar to eBay and Craigslist develop, and other swap–sell–share online markets, swap meets, local markets, and buy-and-share groups become common. Communities become smaller, with work, home, and shopping centers all located within a short distance of each other (walking-distance centralization wins out over driving-distance centralization), and the community general store makes a comeback. In some cases, this is the result of planned rezoning; in other cases, the pace and pressure of change causes local zoning systems to break down altogether, as enterprising households convert their now-too-big homes into corner stores. Low-energy handcrafts, community gardens, small for-profit plots, bicycles, community cooperation, and friend and church networks increase in value and practical utility, leading many people to claim that bottom-up sustainability is breaking out throughout the United States.

4.2 Mega World

Mega World is one of two as-expected scenarios (the other is Suburban World) (see Table 26). Under both Mega World and Suburban World scenarios, the future of the United States is viewed as the continuation of current trends. Economic and population growth are anticipated to be in the most-likely projected range, technology is anticipated to develop along all anticipated paths, and there is a slow adoption of new transportation funding mechanisms. The main difference between Mega World and Suburban World is that, under Mega World, the population is increasingly concentrated into 10 major megaregions. Within these megaregions, there is a

Table 26. Scenario drivers—Mega World.

Driver	Description
Population	• Population continues to follow current tendencies, with population concentrated in megaregions—population reaches 419 million.
Economic Growth	• Real GDP increases by 2.4% per year. • Spending on transportation for federal, state, and local governments stays at the historic average of just under 2% of GDP.
Climate Change, Environment, and Resource Use	• Climate change is slow and predictable. • No major resource shortages or environmental crisis. • Petroleum and other carbon fuel remain important sources of energy.
Transportation	• Transportation technology develops along predictable paths—no breakout, dramatic breakthrough. • State and local government agencies dominate transportation policy planning and implementation.
Land Use and Distribution of Population	• Consolidation of spreading urban and suburban complexes with high-density developing around transportation nodes. • Major city densities would reach some equilibrium, and overall density of the megaregion would increase.

general tendency toward urban concentration and mixed land use; in Suburban World, there is a more decentralized society.

Scenario Story—How the World Might Change: Mega World

After the challenges of the first decade of the 21st century, the next 40 years are relatively quiet for the United States and are recognized as a period of slow but steady improvement in the lives of the American people. Major economic problems, such as the growing federal deficit, are gradually brought under control, and the inherent dynamism of the U.S. economy reasserts itself as the country grows apace with its major international rivals in the advanced economies. Environmental problems remain manageable and within the predicted range, and population grows gradually, with the U.S. population increasing by more than 100 million from 2000 to 2050.

Technology follows anticipated patterns, with gradual adoption of major technological changes. By 2050, there are many automatic, guideway, and connected-vehicle systems along major roads, and self-drive cars are common (but by no means universal). Very-low-emission vehicles, electric cars, and intercity high-speed trains are common, and the country is gradually weaning itself away from its dependence on carbon fuels.

The most striking change is the emergence of megaregions. By 2050, more than 95 percent of all Americans live in these massive urban areas. Although they are not megacities, because there are low-density neighborhoods and cities throughout the megaregions, the 10 population centers dominate the United States. The result is a move toward regional planning and control for many state and local functions. The federal government takes the lead in establishing the intercity and interstate pacts, where new integrated transportation, environment, and economic development authorities form out of the confusing existing pattern to create a more rational and comprehensive planning and decisionmaking structure.

4.3 Suburban World

Suburban World is the second of two as-expected scenarios (the other is Mega World). Under Suburban World (see Table 27), the future of the United States is viewed as the continuation of current trends. Economic and population growth are anticipated to be in the most-likely

Table 27. Scenario drivers—Suburban World.

Driver	Description
Population	• Population continues to follow current tendencies, with population concentrated in megaregions—population reaches 419 million.
Economic Growth	• Real GDP increases by 2.4% per year. • Spending on transportation for federal, state, and local governments stays at the historic average of just under 2% of GDP.
Climate Change, Environment, and Resource Use	• Climate change is slow and predictable. • No major resource shortages or environmental crisis. • Petroleum and other carbon fuel remain important sources of energy.
Transportation	• Transportation technology develops along predictable paths—no breakout, dramatic breakthrough to provide a shock to which the system would need to adapt quickly. • State and local government agencies dominate transportation policy planning and implementation.
Land Use and Distribution of Population	• Population continues to follow current tendencies, with population concentrated in megaregions but distributed in regions at lower average density than Mega World—population reaches 419 million.

projected range, technology is anticipated to develop along all anticipated paths, and there is slow adoption of new transportation funding mechanisms. However, unlike Mega World, technology allows people to live in a variety of settings that best suit their preferences (in the 20th century, these preferences were clearly toward greater decentralization). As a result, there is a generalized move to the suburbs, small towns, and second-tier cities, leading to an America that resembles that of the early 20th century, with a more decentralized population.

Scenario Story—How the World Might Change: Suburban World

During the first half of the 21st century, technology and vibrant economic growth lead to gradual decentralization of America and a return to a settlement and land use pattern similar to that of the late 19th and early 20th centuries. Specifically, economic growth, decentralization of governmental powers as the federal government focuses its activities on its core responsibilities, and technological developments that favor decentralization lead to a United States in which suburbs, small towns, rural areas, and second-tier cities return to predominance. While large cities, such as New York and Los Angeles, remain important, population growth is increasingly seen in smaller cities and rural areas as people take advantage of the freedom technology gives them to live and work in quieter, slower places. Specifically, technology leads to many people working at home or in small facilities near their home. Goods are delivered to central pickup points and then transferred to individual homes via energy-efficient small vehicles. Simultaneously, the increase in fuel prices leads to a decrease in travel and mobility, with most people staying closer to their homes and rarely traveling to other cities or regions in person, and to an increase in people taking advantage of telepresence and virtual reality to experience other places.

In terms of transportation, technology follows anticipated patterns, with gradual adoption of major technological changes so that, by 2050, there are many automatic, guideway, and connected-vehicle systems along major roads, and self-drive cars are common (but by no means universal). Very-low-emission vehicles, electric cars, and intercity high-speed trains are common, and the country is gradually weaning itself away from its dependence on carbon fuels.

Planning and decisionmaking in the transportation space gradually become decentralized down to the local and sub-state regional authorities. State transportation agencies are increasingly hollowed out as responsibilities, funding, and personnel are left to local and sub-state regional

governments. These governments, closer to and more representative of the people, are able to develop clear consensuses about user fees and pay-for-use transportation systems. As a result, these authorities dominate the transportation landscape and make most of the planning decisions. Within this system, there is a general move toward privatization, as local and regional governments attempt to reduce their operating costs by focusing on planning, decisionmaking, and overseeing and contracting out O&M responsibilities for transportation. Gradually, market forces lead to the development of common standards for operation of most surface transportation systems, which leads to a small number of major transportation management companies dominating the transportation market and competing for local transportation business.

4.4 Wonder World

Wonder World is the first of two positive scenarios (the other is Green World) (see Table 28). Under this scenario, there is better-than-currently-expected economic growth and technology development, and adoption is more rapid than currently anticipated. Environmental challenges remain manageable, and population grows rapidly. Although resource prices increase dramatically, the pace of technology improvement and adoption reduces U.S. dependence on many resources as substitutes are found. The spread of new technology and the dynamic state of the U.S. economy mean there is a generalized decentralization of the economy as people use their wealth and the freedom technology brings to live where they choose.

Scenario Story—How the World Might Change: Wonder World

The first half of the 21st century is a period of rapid social, economic, and technological change for the United States. Spurred by dramatic changes in technology in virtually every area, the U.S. economy experiences the Super Boom, a period of more than 40 years of dramatic economic growth. During that period, the U.S. economy doubles in size more than three times, creating a country that is almost unrecognizable by the end of the period from that which had been envisioned in 2000. Super-efficient electrical engines, new biotech fuels, carbon-negative fuels, room-temperature superconductors, artificial intelligence, nanotechnology, and new wonder drugs transform society. New medical technologies enable people to live longer healthier lives,

Table 28. Scenario drivers—Wonder World.

Driver	Description
Population	• Better-than-expected economic growth causes increase in net immigration—population rises to 458 million.
Economic Growth	• Real GDP increases by 3.5% per year. • Spending on transportation for federal, state, and local governments stays at the historic average of just under 2% of GDP.
Climate Change, Environment, and Resource Use	• Climate change is slow and predictable. • No major resource shortages or environmental crisis. • Petroleum and other carbon fuel remain important sources of energy, but alternative sources are rapidly emerging. • By 2050, the price of a gallon of gasoline is more than $7, forcing further innovation and changes in travel behavior.
Transportation	• Radical new technologies are introduced that revolutionize transportation. • MPOs and megaregional organizations dominate transportation policy planning and implementation.
Land Use and Distribution of Population	• Population is concentrated in megaregions. • Mix of megacities and suburban sprawl continue.

such that despite the aging population, people remained active, working and using transportation well into their 80s.

Carbon fuels still play an important role in the economy, but they are being rapidly phased out for more carbon-neutral modes (e.g., fusion and super-efficient solar for electrical power generation, super-fuels for automobiles). For example, carbon-capturing bioengineered algae are used in coal plants to produce biofuel feedstocks, and advanced nanotubes and nonfibers are used to absorb carbon emissions on a massive scale throughout industrial complexes (American Institute of Biological Sciences, 2010). Safer nuclear technology, an emerging fusion power system, and high-generation-capacity wave, solar, geothermal, and wind power provide significant parts of the nation's energy.

For transportation, the dramatic growth in the economy and technology give people a range of choices of where and how to live. Small towns, rural areas, and urban cores all boom. New types of smart suburbs emerge that integrate intelligent transportation technologies with Smart Growth land use strategies. Guideways, intelligent vehicles, super-efficient drive trains, and new fuel sources are nearly universal. Travel between cities is via super-efficient maglevs and other high-speed trains. Freight experiences a major mode shift from road to high-efficiency rail. In cities, smart multimodal systems are common and heavily used. Many people work from home (in smart homes that carefully control carbon emissions) and operate machinery or perform other complex tasks remotely via telepresence systems. Intelligent machines perform many tasks that previously demanded substantial human involvement, thus reducing labor, materials, and energy costs.

4.5 Green World

Green World is another mostly positive scenario (Table 29). Under this scenario, there is rapid economic growth, technology development and adoption, and population growth. However, there is a broad social and political consensus to move toward a more sustainable, green society. As a result, there is substantial investment in green technologies and infrastructure and a movement to a greener, sustainable environment. Despite the apparently benign sound of this scenario, there is substantial regulation and greater social and economic control. Many personal goals and aspirations are limited by the effort to make society greener and more sustainable.

Table 29. Scenario drivers—Green World.

Driver	Description
Population	• Better-than-expected economic growth causes increase in net immigration—population rises to 458 million.
Economic Growth	• Real GDP increases by 3.5% per year. • Spending on transportation for federal, state, and local governments stays at the historic average of just under 2% of GDP.
Climate Change, Environment, and Resource Use	• Climate change is slow and predictable. • No major resource shortages or environmental crisis. • Petroleum and other carbon fuel remain important sources of energy, but alternative sources are rapidly emerging. • By 2050, the price of a gallon of gasoline is more than $7, forcing further innovation and changes in travel behavior.
Transportation	• Radical new technologies are introduced that revolutionize transportation. • MPOs and megaregional organizations dominate transportation policy planning and implementation.
Land Use and Distribution of Population	• Population is concentrated in megacities and high-density urban areas.

Scenario Story—How the World Might Change: Green World

The first half of the 21st century sees development of a broad social and political consensus on the need to develop a sustainable society. Consumer choice and public decisions push investment into green technologies, which leads to the development of an entire suite of green technologies by 2050. The rapid economic growth that this green-revolution creates supports a major social and economic shift toward a new and sustainable society.

One of the most obvious results is the collapse of the suburbs. By 2050, few suburbs remain; families generally live in dense, urban developments. These emerging complexes are enormous habitats of extremely high human population density, containing a variety of residential, commercial, and agricultural facilities that minimize individual human environmental impact. In some cases, they are almost self-contained or economically self-sufficient, where work, life, and even food production are concentrated. At the same time, outside the urban cores, automation reduces the number of individuals and families living in rural areas. Huge biofuel farms are managed by a single family, and food production is largely automated.

The role of carbon-based energy rapidly diminishes as it is rapidly phased out in favor of sustainable, green technologies, including high-generation-capacity wave, solar, geothermal, and wind power. Super-efficient batteries and other devices store energy for use when needed, and solar-electric arrays are common features on most buildings and homes. Personal transportation outside the urban cores is rare; within the urban cores, most transportation occurs via high-efficiency actively managed transit. Personal transportation vehicles are small and based on carbon-neutral fuels (e.g., green electricity, low-carbon alternative fuels). Carbon-capture systems and wind generators are common on most roadways. Interstates are limited to freight, although, in general, freight transportation is shifting from road to rail. The few trips that individuals make between different urban areas are by train.

While the move to sustainability is based on a general social consensus and there are numerous voluntary changes in the private sector and in individuals' lives, the requirement to maintain a sustainable society leads to heavy regulation and social and economic control. Large cars, big homes, and extensive use of air travel for vacations or business purposes are a thing of the past. The high cost of energy rules out these options for any but the very rich. In addition, all major public- and private-sector investments or social or economic choices that might threaten the long-term sustainability of society are severely limited, and private use of resources is controlled by numerous regulations.

CHAPTER 5

Future Challenges and Opportunities for Agencies

As discussed in Section 2.2, changes in policy systems may occur in response to two types of changes: exogenous changes and endogenous changes. Exogenous changes largely result from shocks and from gradual changes over time. Endogenous changes result from social learning that occurs from feedback and from responses to external changes.

This chapter focuses on how a changing external environment will create pressure on individual transportation agencies to change and how the agencies can best use these pressures to learn and to make changes toward a more sustainable system.

Table 30 shows the main exogenous changes that will act on transportation agencies in each scenario. Table 31 shows how these will affect inputs (e.g., demand requirements and the resources available) into the system. Table 32 and Table 33 show the key challenges and opportunities this situation offers to the transportation agencies.

First, there are as many problems or challenges in the positive scenarios as in the negative scenarios. Although there is a general perception that positive scenarios do not produce major problems, the analysis does not support this. For example, in Green World and Wonder World, transportation agencies face numerous problems, ranging from decommissioning nongreen infrastructure and transportation assets (Green World) to repeatedly managing the impacts of disruptive technologies (Wonder World).

Second, not all scenarios will experience greater pressures for change. Crisis World and Wonder World may experience repeated shocks and acute events that provide an impetus for change, but the other scenarios will experience more gradual pressures for change, which may make it more difficult to develop a coalition for change.

Third, the resources available in different scenarios vary greatly. In Crisis World, resources are severely constrained because of slow economic growth and multiple demands on resources to address recurring events. In contrast, resources in Wonder World and Green World are more available, but resource demands remain high because the public is also likely to expect more service and quality from the transportation system along with a higher standard of social well-being.

The following sections discuss in detail each of these pressures for change, inputs, and challenges and opportunities.

Table 30. Exogenous change of transportation agencies under different scenarios.

Scenario	Exogenous Changes (Shocks and Gradual Change)
Crisis World	• Recurrent environmental crises that have dramatic negative impacts on transportation infrastructure • Transportation dislocations (e.g., bridge and freeway interchange postings and closures) from lack of maintenance on transportation infrastructure • Energy and resource price shocks leading to sudden dramatic increases in fuel prices • Gradual, persistent long-term economic decline and slow growth • Reduced federal spending, transfers to state and local government • Reduced resources to support transportation needs • Lack of technological progress • Climate change, causing increased stress on the economy and environment
Mega World	• No major shocks • Gradual centralization to megaregions and megacities
Suburban World	• No major shocks • Gradual decentralization to suburbs and small towns
Wonder World	• Recurrent disruptive technologies, causing dramatic changes to society and the economy • Increasing population growth and greater diversity of population (more diverse ethnic population and aging population) • Increasing economic and technological growth leading to greater demands for mobility of goods and people
Green World	• Increasing population growth and greater diversity of population (more diverse ethnic population and aging population) • Demand that all sectors of society become substantially greener • Greater concentration of population in green urban areas

Table 31. Demand and available resources under different scenarios.

Scenario	Demands and Resources
Crisis World	• Maintain and expand mobility • Afford multiple opportunities for public participation • Support sustainability • Address transportation-related impacts of recurrent environmental crises that have dramatic negative impacts on transportation infrastructure • Address numerous transportation dislocations (e.g., bridge and freeway interchange postings and closures) from lack of maintenance on transportation infrastructure • Respond to energy and resource price shocks by providing alternatives or subsidies • Substantially reduced resources • Dramatically reduced intergovernmental transfers • Gas tax revenue does not keep up with requirements
Mega World	• Maintain and expand mobility • Afford multiple opportunities for public participation • Support sustainability • Shift resources to megaregions and megacities • Gas tax revenue does not keep up with requirements • Growth in user fees
Suburban World	• Maintain and expand mobility • Afford multiple opportunities for public participation • Support sustainability • Decentralization, leading to shift in resources to small towns and suburbs • Gas tax revenue does not keep up with requirements • Growth in user fees
Wonder World	• Maintain and expand mobility • Afford multiple opportunities for public participation • Shift existing infrastructure and transportation systems toward more advanced technologies; respond to rapidly changing technology, including decommissioning older infrastructure • Support wide variety of land use and settlement patterns permitted by technology • Gas tax revenue does not keep up with requirements, but other resources are available • Growth in user fees

Table 31. (Continued).

Scenario	Demands and Resources
Green World	• Move to more sustainable TBL-focused transportation policy • Maintain and expand mobility • Afford multiple opportunities for public participation • Shift existing infrastructure and transportation systems toward more green systems, including decommissioning older, nonsustainable infrastructure • Shift of resources toward concentrated megacity areas • Shift of resources away from less efficient, less sustainable, less dense area • Gas tax revenue does not keep up with requirements, but other resources are available • Growth in user fees • Green taxes and other revenue sources that encourage sustainable behavior

Table 32. Challenges under different scenarios.

Scenario	Challenges
Crisis World	• Recurrent environmental crises that have dramatic negative impacts on transportation infrastructure; greater demands to maintain basic services • Gradual, persistent, long-term economic decline and slow growth mean less resources available to achieve goals • Reduced federal spending and transfers to state and local government mean greater inequality between regions • Lack of technological progress reduces the likelihood of technological solutions • Difficult to maintain all transportation facilities with constrained resources—need to prioritize crucial assets • The best assets that can be maintained and operated with user fees are privatized; agencies must make decisions to maintain or decommission the less-popular bus routes and low-demand bridges and roadways • Limited resources to enforce traffic rules and user safety • Difficulty maintaining funding (worsening economic growth) • State government shrinks in response to declining revenues, resulting in fewer staff at transportation agencies • Poor or missing information leads to bad decisions about funding priorities • Different entities have different priorities, forcing the agency to make tradeoffs in deciding where to allocate limited funds • Need for a process for decommissioning unsustainable infrastructure
Mega World	• Gradual centralization to megaregions and megacities requires changing funding mechanisms and increasing spending on infrastructure • Need to address social and economic equity impacts on the left-behinds outside megaregions (i.e., regions that are trapped in long-term decay and economic decline)
Suburban World	• Gradual decentralization from megaregions and megacities requires changes in funding mechanisms • Need to address social and economic equity impacts of the left-behinds in the cities (i.e., regions that are trapped in long-term decay and economic decline)
Wonder World	• Recurrent disruptive technologies cause dramatic change to society and the economy • Increasing population growth and greater diversity of population (more diverse ethnic population and aging population) • Increasing economic and technological growth, leading to greater demand for mobility of goods and people • Rapid technology innovations, leading to one region implementing a technology that quickly becomes outdated; technologies may not link across regions • Some technologies may require new infrastructure (e.g., new right-of-way for smaller, lighter vehicles; AirTrain rapid transit; multijurisdictional management systems) • Agency staff unable to keep up with technologies and needed changes • New technologies require new standards and safety considerations • Need for new transportation revenue sources as new sources of fuel and propulsion are used
Green World	• Increasing population growth and greater diversity of population (more diverse ethnic population and aging population) • Demand that all sectors of society become substantially greener • Greater concentration of population in green urban areas results in need to address social and economic equity impacts on the left-behinds in less dense regions (i.e., regions where services are in long-term decay and where steady economic decline exists) • Major decrease in personal vehicle travel, requiring agencies to provide sufficient alternatives for intracity and intercity travel • Move away from carbon-based fuels requires new vehicles and new infrastructure

Table 33. Opportunities under different scenarios.

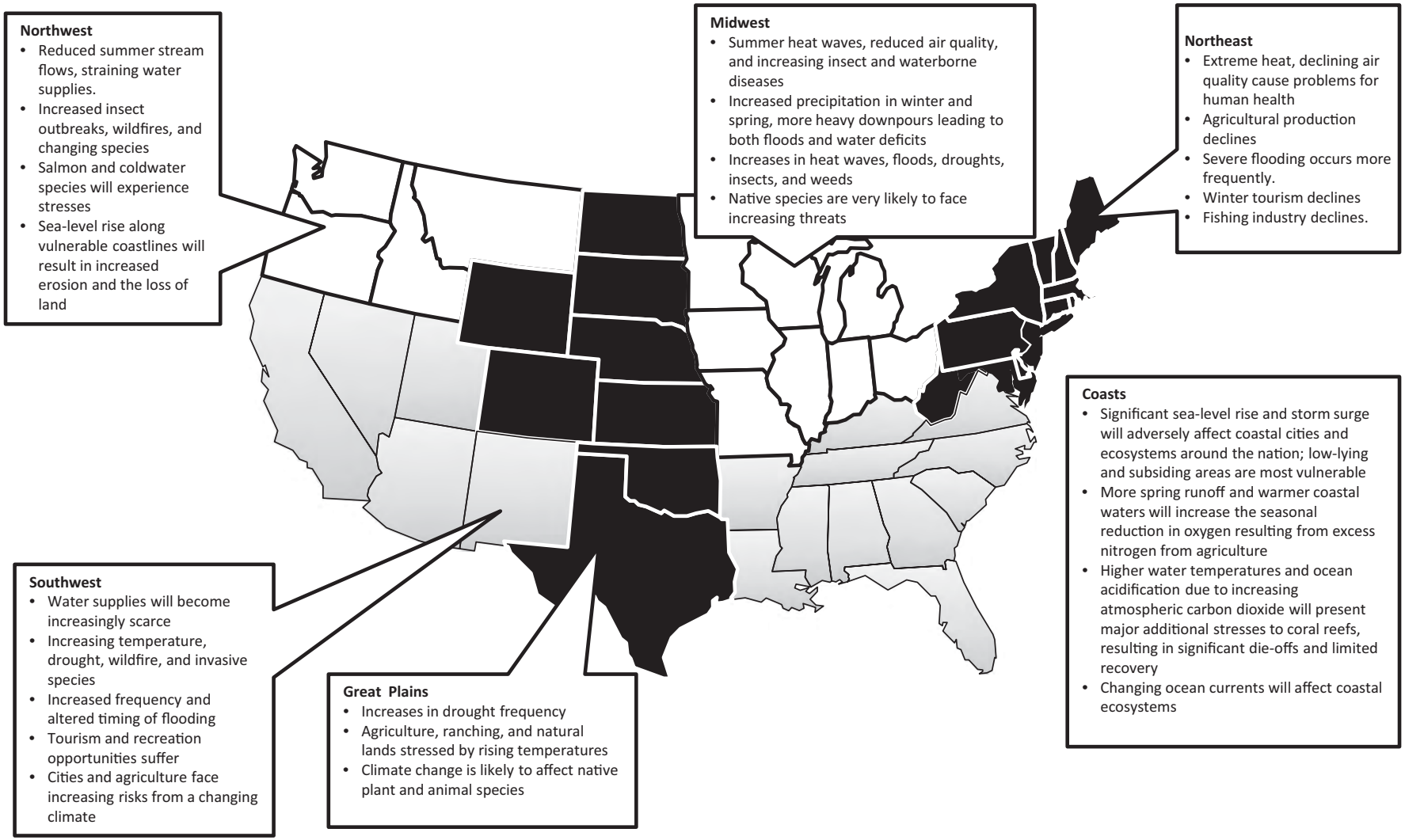
Scenario	Opportunities
Crisis World	• Crisis allows for local and regional response to problem • Region-specific crisis effects increase need for regional, state, and local action and more flexibility • Austerity forces transportation toward low-level sustainability, that is, reduction in the size of the network and focus on key sustainable elements
Mega World	• Gradual centralization to megaregions and megacities means cities and regions have the resources to address problems
Suburban World	• Gradual decentralization means cities and regions have the resources to address problems
Wonder World	• Resources available to support expanding sustainability-based transportation system • Technology facilitates new planning and participation mechanisms, real-time performance management, and control and flexible resource allocation
Green World	• Widespread support for sustainability • Green technologies will be developed that will support sustainability

5.1 Crisis World

Crisis World is the scenario where acute events and transportation disasters are most likely to provide the shock necessary to provoke change. Potential impacts of such events are shown in Figure 12. In Crisis World, every part of the country will experience significant climate change, ranging from sea-level rise and increased storm surges that damage railroad tracks to severe temperature swings that damage bridge joints to flooding and drought (Committee on Climate Change and U.S. Transportation, 2008; this report provides a clear overview of the impacts of climate change and climate change–induced acute events on transportation).

In terms of surface transportation, one of the major likely acute events that will affect transportation is more intense precipitation, leading to increased flooding of coastal roads and rail lines. Expected sea-level rise will exacerbate flooding because storm surges will build on a higher base, and reach farther inland. In fact, the Intergovernmental Panel on Climate Change Fourth Assessment Report on North America identifies coastal inundation from expected sea-level rise and storm surges, especially along the Gulf and Atlantic Coasts, as one of the most serious effects of climate change. The Transportation Research Board (TRB) Climate Change Study projected that transportation infrastructure in some coastal areas along the Gulf of Mexico and the Atlantic Coast will be permanently inundated sometime in the next century (Committee on Climate Change and U.S. Transportation, 2008). Low-lying bridge and tunnel entrances for roads, rail, and rail transit also will be more susceptible to flooding, and thousands of culverts may be too small to accommodate the flows. The resulting erosion and subsidence of road bases and rail beds, as well as erosion and scouring of bridge supports, will further disrupt transportation. The impact of coastal flooding is not limited to coastal areas. Record-breaking rainstorms inland also can cause major recurrent flood damage by swelling rivers and causing massive transportation outages. Equally, changes in seasonal precipitation levels, with more precipitation falling as rain than as snow, offer the potential for major acute events. For example, California's transportation infrastructure could be sensitive to even modest changes in precipitation, whether liquid or frozen. But, when precipitation falls as rain rather than snow, it leads to immediate runoff, thus increasing the risk of floods, landslides, slope failures, and consequent damage to roadways, especially rural roadways, in the winter and spring months.

In the wake of disasters such as those just described, there would be major demands for change. It is likely that federal, state, and local resources would be mobilized to deal with the immediate response and with the long-term rebuilding. However, in Crisis World, there are few resources to address the problems. Crisis World assumes that economic growth will be less than 2 percent over the entire period (barely large enough to keep up with population growth) and that the



Source: Adapted from Committee on Climate Change and U.S. Transportation (2008).

Figure 12. Impacts of 2°C increase in global temperature on the lower 48 states.

federal government, given fiscal constraints, gradually will reduce its role in transportation. Combined with a lack of technological progress and dramatic increases in resource prices, there will be limited resources to address these problems.

Despite these problems, there still will be demands to maintain and expand mobility, support sustainability, address transportation-related impacts of recurrent disasters and acute events, and respond to transportation resource shortages. In fact, the seriousness of the crisis experienced would increase demands on the transportation policy system and require even more resources to be expended at a time when fewer resources are available.

Against this background, the transportation policy system faces numerous challenges, which are easy to identify and innumerate:

- Recurrent environmental crises have dramatic negative impacts on transportation infrastructure.
- Gradual, persistent long-term economic decline and slow growth lead to fewer resources available to achieve goals.
- Reduced federal spending and transfers to state and local government mean greater inequality between regions and less ability for poor regions to resolve their problems.
- Lack of technological progress thus reduces the likelihood of technological solutions.

Paradoxically, the depth of the crisis also may provide new opportunities, as follows:

- Acute events and disasters may provide the shocks that can drive federal, state, regional, and local governments to act. Public leadership may experience a Sputnik moment leading to a new consensus at all levels of government to address crises, adopt new policies, refocus financial support, and mobilize needed programs.
- Region-specific crisis effects increase need for regional, state, and local action and more flexibility. Forced to greater reliance on their own resources, regional, state, and local governments may find new ways to address problems; develop powerful statewide, regional, or local consensus behind action; and, by necessary relaxation of some federal requirements, may gain new flexibility and freedom to pursue new solutions.
- The prolonged austerity of this scenario and the occurrence of sudden shocks to the system may force the public and political leaders to accept the need to prioritize and focus efforts. A new low-level sustainability (e.g., reduce the size of the network, focus on key sustainable elements, reduce mobility, or transfer assets to user control) may emerge where people are willing to make the hard decisions to move ahead.

5.2 Mega World and Suburban World

Mega World and Suburban World anticipate broadly similar futures. Economic growth, population change, and technological progress follow anticipated predicted patterns, and climate and environmental stress are relatively minor. Thus, there are no major shocks that are likely to shake the transportation policy system and require a major rethink of the fundamentals. Instead, there will be two different ongoing changes, which likely will produce very different demands and, therefore, different challenges and opportunities.

In Mega World, the gradual and continuous concentration of the population and economic activity in the megaregions is likely to produce demands to focus more available national resources in these areas. With more than 95 percent of the population centered in these areas, federal, regional, state, and local governments all will be pulled to devote the bulk of their resources to these areas. This produces two major challenges:

- Gradual centralization to megaregions and megacities will require providing additional resources to these regions to support growth and new funding mechanisms to address multistate regional infrastructure investments.

- Centralization will create a number of left-behind regions outside the megaregions that are trapped in long-term decay, economic decline, and depopulation crisis. This will create profound social and economic equity issues that must be addressed.

However, as in Crisis World, Mega World's problems also will create opportunities. Most significantly, the power and economic dynamism of the megaregions mean they will have the resources to address their problems. As noted in this report, the more economically dynamic cities and regions are leaders in sustainability and transportation services. They are experimenting with different kinds of programs, from user fees to congestion charges to integrated land use planning. As these regions grow in strength and wealth, they likely will be in an even better position to address these challenges and work toward increased sustainability.

In contrast, Suburban World will experience the opposite trend. Gradual decentralization will lead to a renaissance in small towns, suburbs, and areas outside the megaregions. In this case, the major challenges will be as follows:

- Gradual decentralization from the megaregions and megacities will require changing funding mechanisms, building new infrastructure to support growing rural and small town populations, and developing a sustainable decentralized infrastructure.
- Social and economic equity issues will arise related to the impacts on the left-behinds in the cities and less affluent rural areas, small towns, and suburbs (i.e., regions that are trapped in long-term decay and economic decline).

The equity issue is especially important; the team's analysis of sustainability experiences indicates that cities with few resources have not been leaders in sustainability. Thus, major economic hubs for the nation (as cities will remain important) may face huge problems in the future in financing sustainability.

As in Mega World, Suburban World also may present considerable opportunities. For example, decentralization of cities and regions will mean that local government is extremely close to its citizens, which may make it easier to develop a consensus behind action and may lead to increased support for sustainability. In addition, the increase in the number of small towns and suburbs will create substantial opportunities for innovation, which in turn may lead to new projects and programs that have unforeseen benefits for sustainability.

5.3 Wonder World

In Wonder World, one of the two positive scenarios, annual economic growth exceeds previous U.S. average growth since the 1860s (on average, slightly more than 3 percent annually), and there are numerous technology breakthroughs. The result is a society that is almost unrecognizable from that of the present day. Multiple disruptive technologies have changed the way people live. As a result, the transportation system has faced repeated demands to update technologies and to respond to user demands. This situation will lead to several challenges, including the following:

- Recurrent disruptive technologies cause dramatic and unanticipated changes to society and the economy.
- Increasing population growth and greater population diversity (more diverse ethnic population and aging population) lead to demands for more diverse transportation services (e.g., growing elderly population requiring assisted mobility).
- Rapid technology innovations may lead to one region implementing a technology that quickly becomes outdated. The technologies may not link across regions.
- Some technologies may require new infrastructure (e.g., new rights-of-way for smaller, lighter vehicles; AirTrain rapid transit; multijurisdictional management systems).
- Agency staff may have difficulty keeping up with the technologies and needed changes.
- New technologies may require new standards and safety considerations.

- A need for new transportation revenue sources arises as new sources of fuel and propulsion are used.

At the same time, new opportunities also will be created:

- Resources may be available to support an expanding sustainability-based transportation system.
- Technology will facilitate new planning and participation mechanisms, real-time performance management and control, and flexible resource allocation.

A disruptive technology or disruptive innovation is a change that helps create a new market that eventually disrupts or destroys an existing market (Kurzweil, 2001a, 2005; Wu, 2010). The effect of the technology is to render an established technology obsolete, along with its associated industrial processes, plants, and supporting infrastructure and to usher in a period of "creative destruction" in which firms, workers, communities, and states must adapt if they are to continue to play a role in the new technology.

Classic examples of disruptive technologies include the automobile, which displaced the horse and railroad as the dominant means of transportation; the microcomputer, which displaced the mainframe and other calculating machines; and digital photography, which displaced chemical photographic film. The defining characteristic of disruptive technologies is that they are not a gradual improvement but rather a radical change in system performance and operations. They initially may appear to have a relatively limited impact, but if a disruptive technology is widely adopted, it can impact or create entirely new markets and ways of life and totally transform society. The Internet, for example, initially was a way to exchange scientific data, but it has since changed society beyond what any of its founders could have imagined. Similarly, the automobile totally reconfigured society between the time of its emergence in the late 19th century and the mid-20th century. The U.S. transportation system has gone through a series of waves with a peak and then a major paradigm shift caused by the emergence of new disruptive technologies (e.g., canal development, steamships, steam locomotives, and the automobile).

In the past, disruptive technologies required many decades to change society. However, the past few decades have seen a vast increase in the speed of innovation and a tremendous decrease in the time between the development of a new technology and its acceptance and use by society as a whole. For example, Kurzweil's (2001a) analysis of technological change concludes that technological progress follows a pattern of exponential growth, what he calls "the law of accelerating returns." He theorizes that other technologies will benefit from and follow the pattern of growth acceleration experienced by integrated circuits predicted by Moore's law.[6] Thus, as information technology becomes omnipresent, its benefits affect more and more elements of society. Furthermore, applying expanding computer power to persistent challenges means that these problems can quickly be resolved. For example, expanded computing power can lead to the development of new materials or new ways of manufacturing materials to higher and higher tolerances, thus improving performance in many industrial applications.

Kurzweil argues that technological progress is increasing so quickly that a time is approaching in which society experiences "technological change so rapid and profound it represents a rupture in the fabric of human history" (Kurzweil, 2001a). He believes that the singularity (when artificial intelligence, biotechnology, and nanotechnology fuse to create a self-sustaining, continuous burst of dramatic innovation) could occur before the end of the 21st century, estimating the date at 2045 (Kurzweil, 2005).

[6] Moore's law describes geometric growth in integrated semiconductor complexity. It predicts that the processing powers of a single chip will double every 18 to 24 months.

Even if one does not accept Kurzweil's vision, there are ample opportunities for major disruptive technologies to emerge between now and 2050, such as the following:

- Development of new alternative fuels or power systems (e.g., vehicle-to-grid electric cars,[7] as-yet unknown biotech-developed super-fuels) and carbon-neutral fuels (i.e., fuels that remove GHG from the atmosphere)
- Development of new freight and delivery systems (e.g., short-distance airborne delivery drones, small airborne vehicles that automatically deliver small high-value payloads)
- At-home customized manufacturing using three-dimensional printers to create most simple items in people's homes rather than having them manufactured elsewhere and delivered
- Vastly improved telepresence and telesubstitution systems (e.g., real-time, three-dimensional, full-immersion virtual projection, where the differences between in-person and virtual interactions nearly disappear)
- Nanotech-driven smart materials in vehicles and infrastructure that monitor their condition and automatically identify and fix problems
- Molecule-level computing and telecommunications that can operate transportation systems and subsystems
- Carbon-based nanotubes as hydrogen carriers for fuel cells
- Nanotech flash capacitors large enough to replace slow-charging electric-vehicle batteries

The challenge of disruptive technologies is that they are not apparent at first sight. Normally, multiple contenders appear when a current technology encounters a systems break (i.e., a point beyond which efforts to improve performance have diminishing returns). For example, the early 20th century saw the development of steam, electric, and internal combustion vehicles, and it was difficult at that time to determine which would triumph. Similarly, high-definition video saw the development of several formats; videotape had two formats; and, initially, television saw a conflict between mechanical television and electronic television (Wu, 2010).

Furthermore, it is unclear how the new technology will be used and adopted. For example, in the early days of radio, the future of broadcasting was seen as belonging to small, decentralized local and regional networks. However, within 10 years, the broadcast system was dominated by two major national networks (Wu, 2010).

Disruptive technologies related to transportation normally require extensive response and support from public policy makers. For example, decisions must be made about how to integrate the new technologies into the current transportation system, what standards will be used, to what degree the infrastructure must be modified, and how these technologies affect current plans and revenue projections. This is the challenging aspect of disruptive transportation technologies. In Wonder World, numerous disruptive technologies would crowd the stage, demanding action and requiring that public policy makers make bets on highly uncertain and unpredictable technological futures. This also has the potential drawback of having the government play a role in picking the winners and losers. Furthermore, the speed of technological advance might be such that the moment one innovation is integrated into the system, another equally disruptive technology emerges.

This rapid technological advance could lead to a paradox whereby the very success of the technological and economic system provides individuals and firms with the resources to develop and adopt technologies but provides insufficient resources for transportation agencies to develop and implement responses. The result may be a disjointed, uneven system that fails to deliver the full benefits of new technologies and makes sustainability planning extremely difficult.

[7] Vehicle-to-grid describes a system in which plug-in electric vehicles communicate with the power grid to sell demand-response services by either delivering electricity into the grid or by throttling their charging rate. Vehicle-to-grid can be used with plug-in battery electric cars and hybrids with grid capacity. Because most vehicles are parked an average of 95 percent of the time, their batteries could be used to let electricity flow from the car to the power lines and back, with a value to the utilities of up to $4,000 per year per car.

5.4 Green World

Green World assumes a radical social shift in favor of a green and sustainable future. Although at first sight this scenario may seem extremely positive, it will produce many pressures for change. Most significantly, it will require whole-scale replacement and redesign of the current transportation infrastructure to meet the new demands and expectations for sustainability. As individuals move into more concentrated sustainable communities (probably in urban areas), there will be massive demand for transportation, which in turn will lead to new transportation requirements. Thus, in Green World, as in Wonder World, almost as many challenges will arise from success as would arise from negative events in Crisis World. For example, there may be dozens of different options for new green technologies that require extensive infrastructure reconfiguration and no obvious winner. Similarly, decommissioning, reorienting, or redesigning gray infrastructure to meet the demands of new green public preferences may present considerable challenges to transportation agencies.

Specific challenges associated with Green World include the following:

- Increasing population growth and greater diversity of population (more diverse ethnic population and aging population) lead to demands for much more diverse transportation services (e.g., increasing elderly population requiring assisted mobility).
- There is a demand that all sectors of society become substantially greener.
- Greater concentration of population in green urban areas leads to a need to address equity impacts of the left-behinds in less dense regions (i.e., regions that are trapped in long-term decay and economic decline).
- Major decreases in personal vehicle travel mean that agencies must provide sufficient alternatives for intracity and intercity travel.
- Moving away from carbon-based fuels may require new vehicles and new infrastructure.

Opportunities in Green World will include the following:

- Social and political consensus on green policies and sustainability mean that resources will be available to support an expanding sustainability-based transportation system.
- Technology will facilitate new planning and participation mechanisms, real-time performance management and control, and flexible resource allocation.
- Green technology will support sustainable transportation.

CHAPTER 6

Addressing the Functional Gaps under Scenarios

This chapter discusses how transportation agencies might address key functional gaps under different scenarios. Section 6.1 presents some general principles for managing public-sector change that are relevant to all scenarios based on analysis of the scenarios; review of the literature on sustainability, transportation, and public policy; and interviews with SMEs. Section 6.2 addresses each potential sustainable end state and probable conditions under the various scenarios. Finally, Section 6.3 identifies organizational, policy, and management implications and strategies for agencies to consider staying ahead of evolving conditions and policy systems related to TBL sustainability.

6.1 Key Principles in Preparing for TBL Sustainability under All Scenarios

As emphasized throughout this report, national and global futures are highly uncertain. On the one hand, a convergence of technology and economic growth may deliver substantial benefits and opportunities. On the other, society may face an environmental and social crisis. Over the next 30 to 50 years, the United States will likely experience significant demographic shifts and economic changes, perhaps on the order of the urbanization of the late 19th and early 20th centuries. In some regions, population may shrink to near presettlement levels; in others, concentrations of people and economic activity may reach high levels. But it is important to bear in mind that the nation has experienced repeated bouts of major technological, social, and economic change over the last two centuries: the railroad system, instantaneous information transmission over long distances, the automobile highway system, two world wars, the Cold War, the civil rights movement, Vietnam, and Watergate. So although future challenges and opportunities may be significant, the social and economic resources available to respond are also formidable.

The following key points should be kept in mind about the distinctly different focus of TBL sustainability under each of the proffered scenarios:

- TBL sustainability is a concept that seeks to achieve a particular (and sustainable) balance of social, economic, and environmental factors—to meet and preserve a standard of living quality *that is demanded by the public at a time and a place, region, or nation.*
- "One size" of TBL sustainability definitely does *not* fit all scenarios. The specific TBL balance demanded by the public is affected by existing conditions (each scenario), including politics, culture, demographics, history, and probably many other factors.
- In each scenario, societal standards for TBL sustainability will seek to preserve or improve all of the "bottom lines," but where conditions permit, society may bias the focus on improving the value of one or more of the bottom lines.

So for each scenario, a sustainable society can logically follow a different balance of public focus between each of the three bottom lines, as the public seeks to improve or—at the least—to preserve a desired overall standard of living quality for future generations.

The distinctions in the focus of TBL sustainability under Wonder World versus Green World is a good illustration. The distinctions are accounted for by plausible differences in the public demands for focus on each of the three bottom lines under these two scenarios:

- **In the Wonder World scenario**, all three bottom lines are assumed healthy, and there is envisioned to be a greater focus on investment in the economy and social welfare than in the environment. Economic growth is channeled toward greater personal income, higher individual consumption, and technology investment is focused on personal consumption and societal consumption. In this scenario, individuals reach substantially higher standards of living in conventional terms. The environment does not suffer but is probably not raised to a higher standard in the (then) near term.
- **In the Green World scenario**, there is a much stronger social consensus and investment focus on improving the environmental pillar of the TBL while sustaining acceptable economic and social well-being. As a result, much more of the wealth generated by economic growth is assumed to be invested in environmental goods (e.g., cleaner air and water, restoration of endangered or severely damaged habitats). Thus, while employment and economy may be solid, there is less personal real disposable income due to clear public consensus to devote a larger share of the GDP to environmental protection and management. But the economic conditions are deemed acceptable and sustainable by the public, with prospects for an improved environment for themselves and future generations. The research team described sustainability in Green World as "managed austerity." The austerity represents a deliberate collective decision to consume less as individuals and spend more on the environment, and to sustain that life style for the next generations. This is clearly a different TBL balance than that demanded by the Wonder World society.

If TBL sustainability does evolve as an overarching organizing principle (or policy system) for transportation, experience and literature on sustainability-related initiatives suggest that some basic principles should be kept in mind for decisionmaking and change response, including the following:

- **Adopt a precautionary approach to policymaking and decisionmaking.** A precautionary approach to decisionmaking means taking into account the level of risk, using existing knowledge, and accounting for uncertainties. The approach recognizes a social responsibility to minimize the community's exposure to harm as much as possible when detailed situational analysis and investigation have found a plausible risk arising from a decision or policy choice. This precautionary approach should be used when making planning decisions that relate to new policy as well as when changing existing policy. The precautionary approach is even more advisable when there is a high level of uncertainty, where decisions are effectively irreversible, or where there are effects of low probability but potentially high impact (e.g., the decision to locate transportation infrastructure assets near areas susceptible to floods or rising sea water).
- **Choose flexible or adaptive management options and build internal adaptive capacity.** Flexible or adaptive management strategies are based on the insight that knowledge and understanding of social, economic, and environmental conditions are inevitably partial; limited; held in different forms (e.g., data, tacit knowledge and understanding, experiential information); and widely distributed among different individuals, groups, and organizations. As such, no single entity can ever develop an all-encompassing vision of the world that correctly models all factors and elements likely to affect the outcome of a decision or public policy. A more realistic approach is to adopt a flexible or adaptive management strategy. Under this approach, policies are adopted and implemented incrementally or as small steps over time. The capability for policy

change based on new information is built into the process such that the implementation or design of a program can be adjusted gradually. Monitoring is an important part of this approach: Data must be available so policy makers can identify unintended consequences and act quickly to limit damage or build on successes. More open, responsive, and resilient structures that focus on outcomes rather than process and possess an expectation of change can be helpful, but this may require a culture change and a different organizational and institutional system. A change-expecting, resilient organization provides safety (but not necessarily security or stability) in the midst of change; manages the emotional consequences of continuous mission and organizational transformation and change (e.g., anxiety, grief at the loss of status or role); and emphasizes constant learning, development, and internal capability growth.

- **Use no- or low-regrets options.** No- or low-regrets options are built around the idea that, insofar as it is possible, good policy should bring benefits regardless of the reasonable future. Although this idea might reduce the potential for a policy to maximize benefits by "doubling down" on an attractive near-term policy option, caution may ultimately increase constituent value, because it can help agencies deal with uncertainty. In practice, this means moving away from simple statements of the costs and benefits of policies or infrastructure investments and moving toward a more nuanced approach that explicitly acknowledges uncertainty and clearly expresses benefits as a range that could occur under different conditions. For example, under this approach, a decisionmaker may have to choose between two policies—one that produces an expected net social benefit of $1 million and one that produces a range of net social benefits from $500,000 to $750,000. Under classic cost–benefit analysis, the decisionmaker would select Option 1 (Option 1 net benefit exceeds Option 2). However, if the benefit from Option 1 would only accrue if the future were exactly as predicted, while Option 2 benefits would accrue under a wide range of scenarios, the decisionmaker would select Option 2 as the no- or low-regrets option. Thus, the decisionmaker would accept suboptimal decisionmaking in exchange for an "insurance policy" against uncertainty. It should be noted that the literature on these policy approaches stresses that no- or low-regrets options are particularly suitable for near-term projects where small investments can deliver obvious and immediate benefits no matter what the outcome and provide experience on which to build further actions and support for more ambitious policy programs (Eales et al., 2006).
- **Avoid burden shifting.** This principle suggests that decisionmaking and policymaking should not resolve problems by shifting them to other areas, jurisdictions, modes, or economic or social sectors. For example, congestion management policies might deal with the problems in one area by pushing traffic to another or create new economic or social problems by imposing costs on vulnerable commerce or populations. This principle emphasizes the need to integrate policymaking across departments and agencies. It is difficult to apply and often impeded by legislative mandates, but it is vitally important in a TBL policy system.
- **Deal with "messy" futures by building citizen cooperation and enabling innovation.** Social, environmental, and economic innovation can be messy and confusing. The future rarely comes as a unitary, easily understood event that everyone immediately comprehends and accepts. The future arrives at an uneven pace. As the science fiction writer and futurist William Gibson observed, "The future is already here—it is just not evenly distributed" (National Public Radio, 1999). For example, for someone living in northern California and working in the technology industry, it can seem that Wonder World is well on its way to arriving. Similarly, for someone living on the Gulf Coast and still recovering from hurricanes Katrina and Rita and the Deepwater Horizon oil spill, it might seem that Crisis World is already here. Furthermore, even generally experienced events can be open to a wide range of interpretations. For example, a review of 21 books on the 2008 financial crisis found little consensus on the basic facts of the crisis, its causes, and the policies that should be adopted in response (Lo, 2012). Inevitably, politics, different interests and experiences, and personal biases affect interpretations. The "messiness" of the future is part of the reason why locations

pursuing strong TBL initiatives have adopted the precautionary principle and the other methods discussed in this section. However, the messy and "joint and uneven" nature of change is also a reason transportation agencies may want to prepare for the future by building relationships with communities and groups that are affected differently, developing connections with individuals with different perspectives, working across jurisdictional borders, and accepting variability. In this sense, government can act as an enabler of innovation and communication. Change experienced "on the ground" can be an important part of the solution to emerging problems. Government-enabled collaboration can incorporate a diversity of perspectives, allow experimental policy design, and create an environment where it is possible to fail safely.

- **Make public participation a more positive force.** Technological, social, legal, institutional, political, and economic changes have created an environment in which citizens, social groups, activists, and "super-empowered individuals" are a fact of life in public policymaking. Whatever happens in the future, it is unlikely that this environment will change (Friedman T. L., 2000). Most aspects of public policymaking and implementation are transparent and will become more open to citizen review and public comment and, most likely, more direct engagement in decisionmaking. This does not mean that every decision and program will be slowed down or impeded by public involvement processes. Public participation can be a vital, positive force. Indeed, the experience of sustainable transportation policy suggests that public participation is a critical element to support successful policy. Citizens are "co-producers" of these outcomes—that is, they are critically involved in the success of a policy, because substantial behavioral change is required from citizens if a policy is to deliver its full benefits (Brandsen and Pestoff, 2006). Successful approaches are likely to be those that: design policy around the assumption that the public is involved in decisionmaking; consider the public critical to successful implementation; and build public trust to enable the right decisions in periods of uncertainty.

This last principle is of critical importance in preparing for the shift to a TBL-based policy system. Although effective public policy requires a democratic foundation, traditional participation models may need to be expanded to suit the increasing complex challenges of TBL. In spite of positive strides in public involvement today, there remains room for improvement even under today's policy systems.

6.2 Agency Roles and Relationships under the Scenarios

This section discusses actions and policies that agencies could undertake under the scenarios. Generally speaking, certain policies, actions, programs, and concepts are appealing no matter the scenario, as illustrated in Figure 13.

In the near term, all scenarios appear to be similar. Major differences only begin to become apparent in the mid term, and truly significant changes only occur in the long term. Thus, major policy differences are only really apparent in the long term (assuming that external conditions drive policy). Therefore, recommendations for options focus on the near- and mid-term period and provide flexibility and adaptability for the future (1) to provide useful, usable, actionable information and (2) to not move transportation agencies toward policies that may not be practical or appropriate for future scenarios that could develop. Table 34 shows a likely TBL end state along with plausible roles and relationships that would exist among different government entities under the different scenarios. As the table shows, the future scenarios developed for this research range from "crisis austerity" conditions to "managed austerity" conditions, with a range of possibilities in between. The research team believes that although the roles and relationships are necessarily somewhat speculative, public policy logic supports them. The rest of this section discusses the key themes summarized in Table 34.

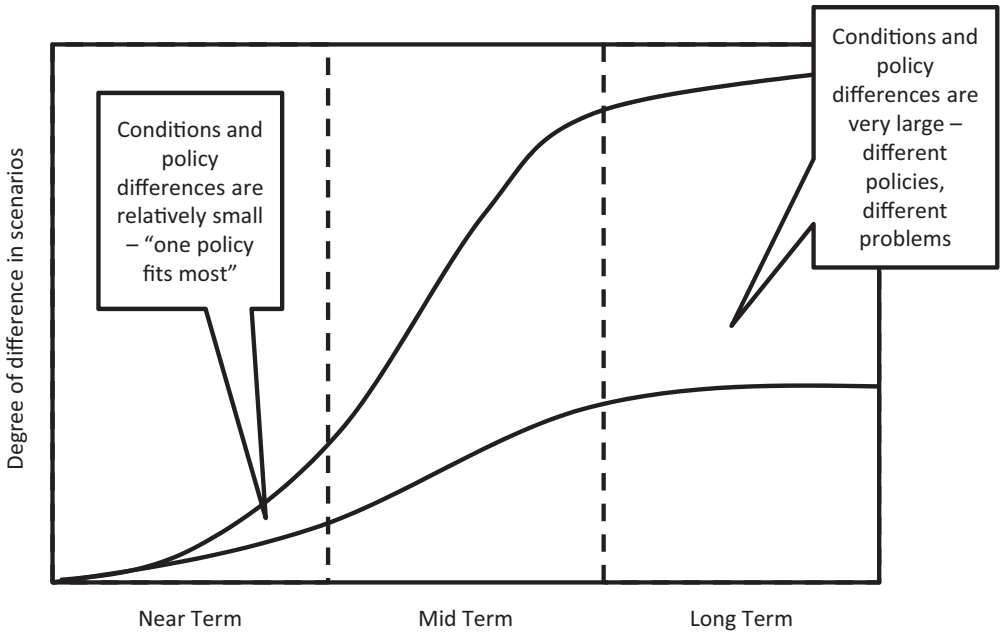


Figure 13. Policy change and scenario differentiation.

In the Crisis World scenario, crisis austerity represents a forced march to a somewhat balanced TBL, as ongoing environmental crises, recession conditions, and social needs all compete for attention. However, this TBL will likely be combined with a low standard of living, reduced mobility, and reduced transportation options. Furthermore, the unpredictable nature of Crisis World means sustainability will constantly be under threat and will need closer attention to maintain stability.

In the Mega World scenario, the main changes will be in consolidation and growth of mega-regions. Those regions will likely strongly influence TBL policy, as they do for many sustainability initiatives today. In contrast, Suburban World is a dispersed, decentralized society that will have to manage sustainability at a more local level and on a smaller scale, raising more challenges for coordination and resource balancing.

It is important to understand the challenge that Suburban World would pose to sustainability. Suburban World envisions a radical decentralization of political and economic power. Small towns and individual homesteads would emerge as major economic hubs as people take advantage of the opportunities technology offers to move away from crowded cities. This would lead to enormous proliferation of interests, plans, and goals. Under a reenergized localism, the more than 87,000 governments in the United States would be actively involved in planning for sustainability. The simple number of governments would make coordination difficult to achieve. Furthermore, sustainability requires careful balancing and coordination. For TBL sustainability to function properly, there must be tradeoffs. As the number of participants in these tradeoff decisions increases, the difficulty in developing these tradeoffs would increase exponentially. In addition, the range and diversity of communities would be extremely great. They could vary from wealthy communities deeply committed to sustainability to poor communities willing to relax sustainability standards to attract economic development.

On the positive side, the decentralization of authority and economic power would mean that local communities could take on a larger burden in maintaining and operating their transportation

Table 34. Plausible roles under future scenarios.

Scenario	Overall Orientation of Transportation Policy	Plausible Roles			
		Federal Agencies	State Agencies	Regional Transportation Organizations	Local Governments
Crisis World	Crisis austerity—TBL with a low standard of living	Strong influence on crisis response and transportation planning—focus on emergency planning, response, and action; focus on major transportation corridors and TBL tradeoffs	Strong influence on crisis response and transportation planning—focus on emergency planning, response, and action; focus on key transportation corridors and TBL tradeoffs in the state	Moderate role in planning response, coordinating rebuilding and rehabilitation programs, and shaping priorities for use of scarce transportation resources	Front-line responders and managers of crisis response—manage local TBL compliance
Mega World	Regionally managed TBL	Possible diminished role in megaregions; more focus on intercity corridors, national network efficiency, and support of rural infrastructure	Possible diminished role in megaregions; more focus on intercity corridors and support of rural infrastructure; more regional, interstate interaction and coordination needed, particularly in megaregion areas	Regional and megaregional planning entities likely play stronger parts in coordinated TBL-related decisionmaking	Key roles in planning and implementation. Influence in TBL policy could be strengthened depending on funding structures in respect to user fees
Suburban World	Decentralized TBL—more numerous and more distributed initiatives	Probably similar focus and interest as present; TBL initiatives are more distributed; federal and state agencies may have to share new roles if urban influence declines	Increased influence and role in state transportation and TBL management; coordination of increased numbers of players in transportation planning and TBL issues	Similar to current roles, possibly diminished by increased dispersion of population and transportation patterns	Key roles in planning and implementation; influence in TBL policy could be somewhat stronger depending on funding structures in respect to user fees
Wonder World	Managed sustainability—high living standards and management of systems to deliver TBL	Increased challenges in assisting agencies with rapid technological changes; helping reinvent infrastructure, if needed; otherwise, similar or somewhat diminished influence, depending on how the public pays for transportation	Increased challenges in assimilating rapid technological changes and effects of infrastructure changes as well as faster demographic shifts; overall influence may depend on how the team pays for transportation; TBL will be a difficult management challenge, as rules and assumptions will change faster	Regional and megaregional planning entities likely play stronger parts in coordinated TBL-related decisionmaking	Key decisionmakers on adoption and implementation of new TBL-related technology
Green World	Managed austerity—TBL but lower living standards	Major role in national TBL policy systems via development of new standards and work with states and localities to integrate and derive maximum synergy from state and local TBL programs	Major role in balancing state TBL programs, working with localities to deliver TBL, and managing transportation infrastructure changes	Regional and megaregional planning entities likely play stronger parts in coordinated TBL-related decisionmaking	Major decisionmakers on the implementation of new TBL-related technology; involved in key decisions to decommission or reuse older infrastructure

resources. Similarly, the plurality of approaches to managing transportation would lead to huge opportunities for experimentation and innovation. However, this in itself could be a challenge. Fuller (2002) in his analysis of radical decentralization in education that has occurred with the charter schools movement notes the "paradox of radical decentralization" (Fuller, 2002). The paradox is that, although decentralization allows innovation and experimentation, it can also cause groups to retreat into their parochial interests and become resistant to change. Thus, there is a vast set of innovations, but managers of new organizations have deep emotional commitment to practices and have the power and authority to resist change.

In the Wonder World scenario, new technology will likely create opportunities for a much more dynamically managed system in which information and sensor technologies could provide minute-by-minute management of factors that affect TBL. Simultaneously, technology and economic growth will deliver a high standard of living and numerous transportation and mobility options. In contrast, Green World represents a managed austerity condition. That is, the strength of the social commitment to TBL and green choices means that society has accepted environmental tradeoffs that may reduce or limit standards of living and strength of economy.[8]

It should be emphasized that Green World is based on the assumption that there is a broad social consensus around the idea of sustainability. However, this does not mean that all interests and stakeholders will automatically agree to how the costs and benefits of sustainability should be distributed. To date there has been no comprehensive assessment of the likely costs of introducing sustainability planning on a large scale. Most analyses present a uniformly positive assessment of benefits. However, these assessments frequently include some valuation of natural resources or other nonmarket goods. In reality, these benefits do not present themselves in a clear monetary fashion, and nontechnical individuals often have difficulty understanding how and why they have been monetized. Without these benefits, sustainability may not present as an appealing business case. Furthermore, it is inevitable that in some places, sustainability will require that some individuals receive fewer benefits and higher costs than others. As basic economics tells us, scarcity is inevitable (i.e., everyone cannot have everything he or she wants), and choices must be made. These choices will benefit some stakeholders over others at least some of the time (e.g., permanent win–win solutions are not available all the time). For example, sustainability in Green World may mean that individuals cannot use personal gasoline vehicles in urban areas or expect state or local government to maintain roads to extremely low-density rural areas, discouraging suburban growth and large homes. Furthermore, considering the pluralist and open nature of American society, even a broad consensus will not be shared by some people. Undoubtedly some individuals would "drop out" of the sustainability consensus and insist that they have a right to continue to live in "pre-sustainable" outposts (e.g., use older, gasoline-powered vehicles; live in larger, less dense, car-based communities). Thus, even though the research team assumed broad support for sustainability under Green World, individual stakeholders will still need to be "sold" and persuaded as to the benefits of specific sustainability programs. As such, Green World may require substantial consensus-building efforts to develop support for specific sustainability measures.

6.3 Functional Implications under Each Scenario

Table 35 shows key requirements for high-level transportation functions performed in a TBL society under the different scenarios—assuming that our society will eventually evolve to embrace TBL as an organizing principle. As can be seen, the basic functions need to be performed

[8]Green World is an example of a strong TBL policy system; a weak TBL is characterized by considering all three bottom lines (people, planet, profit) as more or less equal capital (Turner, 1992).

Table 35. Functional implications under each scenario.

Scenario	Response of Transportation Agencies
DEVELOPING CONSENSUS ON NEEDS AND GOALS	
Crisis World	• Crisis driven—identify resources needed and work with experts and key stakeholders to identify key resources for sustainability
Mega World	• Need new mechanisms to coordinate needs assessment and develop consensus on goals at a megaregional level • Decisionmakers and stakeholders work proactively together, creating goals and plans to support transportation needs sustainably; developing consensus is a major goal; active outreach and consensus building
Suburban World	• Radically decentralized society provides opportunities for public participation and direct democracy in decisionmaking • Decisionmakers and stakeholders work proactively together, creating goals and plans to support transportation needs sustainably; developing consensus is a major goal; active outreach and consensus building
Wonder World	• New technologies provide opportunities for public participation and direct democracy in decisionmaking • Decisionmakers and stakeholders work proactively together, creating goals and plans to support transportation needs sustainably; developing consensus is a major goal; active outreach and consensus building
Green World	• Decisionmakers and stakeholders work proactively together, creating goals and plans to support transportation needs sustainably; developing consensus is a major goal; active outreach and consensus building
PLANNING AND PROGRAMMING	
Crisis World	• Focus on prioritizing key assets and developing policies to manage crisis and lead to sustainability
Mega World	• Need to develop megaregional planning and programming mechanism with the authority to work with state and local governments to implement megaregional initiatives • Emphasize flexibility, accessibility, connectivity, and quality (closer, better) • Emphasize multimodal and connections between modes • Manage transportation and mobility demand • Emphasize integrated planning combining transportation (all modes) with other relevant areas (environment, demographic trends, cultural resources) and levels of government • Use analysis to interrupt and reverse trends (predict and prevent) • Work from preferred vision to planning and provision (deliberate and decide)—build scenarios, backcast, deliberate, and decide • Flexible regional focus engages multiple jurisdictions • Planning and investment decisions are driven by reliable and up-to-date data that reflects full range of impacts from investing in transportation
Suburban World	• Need to develop mechanisms to coordinate decentralized programs • Emphasize flexibility, accessibility, connectivity, and quality (closer, better) • Emphasize multimodal and connections between modes • Manage transportation and mobility demand • Emphasize integrated planning combining transportation (all modes) with other relevant areas (environment, demographic trends, cultural resources) and levels of government • Use analysis to interrupt and reverse trends (predict and prevent) • Work from preferred vision to planning and provision (deliberate and decide)—build scenarios, backcast, deliberate, and decide • Flexible regional focus engages multiple jurisdictions • Planning and investment decisions are driven by reliable and up-to-date data that reflects full range of impacts from investing in transportation

Table 35. (Continued).

Scenario	Response of Transportation Agencies
Wonder World	• New technology provides the ability to model and design programs with much more accuracy and fidelity • Emphasize flexibility, accessibility, connectivity, and quality (closer, better) • Emphasize multimodal and connections between modes • Manage transportation and mobility demand • Emphasize integrated planning combining transportation (all modes) with other relevant areas (environment, demographic trends, cultural resources) and levels of government • Use analysis to interrupt and reverse trends (predict and prevent) • Work from preferred vision to planning and provision (deliberate and decide)—build scenarios, backcast, deliberate, and decide • Flexible regional focus engages multiple jurisdictions • Planning and investment decisions are driven by reliable and up-to-date data that reflects full range of impacts from investing in transportation
Green World	• Emphasize flexibility, accessibility, connectivity, and quality (closer, better) • Emphasize multimodal and connections between modes • Manage transportation and mobility demand • Emphasize integrated planning combining transportation (all modes) with other relevant areas (environment, demographic trends, cultural resources) and levels of government • Use analysis to interrupt and reverse trends (predict and prevent) • Work from preferred vision to planning and provision (deliberate and decide)—build scenarios, backcast, deliberate, and decide • Flexible regional focus engages multiple jurisdictions • Planning and investment decisions are driven by reliable and up-to-date data that reflects full range of impacts from investing in transportation
BUDGETING AND RESOURCE ALLOCATION	
Crisis World	• Focus on prioritization and identifying and funding basic needs for sustainability • Identify how noncore functions can be shifted to other partners • Identify the ability of government to support the long-term cost of investments from a fiscal and TBL point of view
Mega World	• Need to develop megaregional mechanisms to budget and fund interstate and interlocality megaregion-wide projects • Use integrated and cooperative budget process • Incorporate full social, environmental, fiscal, economic, and other costs into planning and provision—use full cost accounting • Flexible—funds flow to program areas, regions, and modes, where they will make the biggest impact on societal sustainability • Independence—consistent funds provided by dedicated transportation funds with long-term commitment to TBL priorities
Suburban World	• Use integrated and cooperative budget process • Incorporate full social, environmental, fiscal, economic, and other costs into planning and provision—use full cost accounting • Flexible—funds flow to program areas, regions, and modes, where they will make the biggest impact on societal sustainability • Independence—consistent funds provided by dedicated transportation funds with long-term commitment to TBL priorities
Wonder World	• New technology provides ability to manage funding and track spending with much more accuracy and fidelity • Use integrated and cooperative budget process • Incorporate full social, environmental, fiscal, economic, and other costs into planning and provision—use full cost accounting • Flexible—funds flow to program areas, regions, and modes, where they will make the biggest impact on societal sustainability • Independence—consistent funds provided by dedicated transportation funds with long-term commitment to TBL priorities

(continued on next page)

Table 35. (Continued).

Scenario	Response of Transportation Agencies
Green World	• Use integrated and cooperative budget process • Incorporate full social, environmental, fiscal, economic, and other costs into planning and provision—use full cost accounting • Flexible—funds flow to program areas, regions, and modes, where they will make the biggest impact on societal sustainability • Independence—consistent funds provided by dedicated transportation funds with long-term commitment to TBL priorities
RULEMAKING AND REGULATION	
Crisis World	• Reduced public participation as a result of crisis situation and increased ad hoc regulation
Mega World	• Public–expert partnership in developing regulation and rules—experts invite and encourage public participation • Bias for flexible, voluntary regulation • Open to a wide plurality of interests, stakeholders, and activists • Involve public substantially during the entire rulemaking process • Cooperative and consultative • Emphasize voluntary regulation
Suburban World	• Public–expert partnership in developing regulation and rules—experts invite and encourage public participation • Bias for flexible, voluntary regulation • Open to a wide plurality of interests, stakeholders, and activists • Involve public substantially during the entire rulemaking process • Cooperative and consultative • Emphasize voluntary regulation
Wonder World	• Public–expert partnership in developing regulation and rules—experts invite and encourage public participation • Bias for flexible, voluntary regulation • Open to a wide plurality of interests, stakeholders, and activists • Involve public substantially during the entire rulemaking process • Cooperative and consultative • Emphasize voluntary regulation
Green World	• Public–expert partnership in developing regulation and rules—experts invite and encourage public participation • Strong regulatory system—clear tradeoffs between TBL • Open to a wide plurality of interests, stakeholders, and activists • Involve public substantially during the entire rulemaking process
SERVICE AND PROJECT DELIVERY	
Crisis World	• Focus on limited service delivery, transferring nonkey functions to other entities
Mega World	• Sustainability embedded in all business processes (e.g., procurement, O&M) • Sustainability performance measured and reported for continual improvement
Suburban World	• Sustainability embedded in all business processes (e.g., procurement, O&M) • Sustainability performance measured and reported for continual improvement
Wonder World	• New technology provides ability to manage programs and transportation events and trends in real time with much more accuracy and fidelity • Sustainability embedded in all business processes (e.g., procurement, O&M) • Sustainability performance measured and reported for continual improvement
Green World	• Sustainability embedded in all business processes (e.g., procurement, O&M) • Sustainability performance measured and reported for continual improvement
COMPLIANCE AND DISPUTE RESOLUTION	
Crisis World	• Emergency decisionmaking—more hierarchical, less democratic
Mega World	• Minimize politics • Emphasize "deliberate and decide" • Stronger compliance ethics, reducing disputes
Suburban World	• Minimize politics • Emphasize "deliberate and decide" • Stronger compliance ethics, reducing disputes
Wonder World	• Minimize politics • Emphasize "deliberate and decide"
Green World	• Minimize politics • Emphasize "deliberate and decide" • Stronger compliance ethics, reducing disputes

Table 35. (Continued).

Scenario	Response of Transportation Agencies
INTERNAL EDUCATION, TRAINING, AND CULTURAL CHANGE	
Crisis World	• Internal education focus on crisis-related issues and development of a "survival sustainability" culture
Mega World	• Focus on multidisciplinary workforce—acceptance of flexible standards • Commit to sustainability education, training, and internal incentives to be sustainable • Culture of sustainability and stewardship • Performance standards and incentives associated with sustainability
Suburban World	• Focus on multidisciplinary workforce—acceptance of flexible standards • Commit to sustainability education, training, and internal incentives to be sustainable • Culture of sustainability and stewardship • Performance standards and incentives associated with sustainability
Wonder World	• Focus on multidisciplinary workforce—acceptance of flexible standards • Commit to sustainability education, training, and internal incentives to be sustainable • Culture of sustainability and stewardship • Performance standards and incentives associated with sustainability
Green World	• Focus on multidisciplinary workforce—acceptance of flexible standards • Commit to sustainability education, training, and internal incentives to be sustainable • Culture of sustainability and stewardship • Performance standards and incentives associated with sustainability
OUTREACH AND COMMUNICATIONS	
Crisis World	• Focus on explaining to the public the rationale behind emergency measures, decommissioning, repair and rebuilding, and need to move toward sustainability • Build support for initiatives and programs that require reduced mobility and fewer services
Mega World	• Focus on explaining to the public the rationale for megaregional planning and the importance of dealing with issues outside the megaregion
Suburban World	• Focus on explaining to the public the responsibilities of a rapidly decentralizing system and dealing with challenges of managing sustainability in a decentralized network
Wonder World	• Focus on explaining to the public the rationale behind different technology selections and rebuilding transportation infrastructure to address new technology issues and sustainability • Build support for initiatives and programs that require a move to new technologies and greater sustainability
Green World	• Focus on explaining to the public the rationale behind green measures and rebuilding transportation infrastructure to address green issues and sustainability • Build support for initiatives and programs that require reduced mobility to support sustainability

to support the requirements of a TBL end state, regardless of the future scenario. The main effects the various scenarios will have on the high-level functions are that the *opportunities and challenges* presented to transportation (in performing the functions) will likely arise in distinctly different, scenario-specific ways along the following scenario features:

- Political and demographic landscape and rate of change
- Demand (and ability to pay) for available modal transportation services
- Outlook for energy availability and cost
- Pressure on the health of the environment
- Age and health of infrastructure
- Priorities and needs of society

When TBL is assumed as an end state and the challenges are viewed holistically, several key themes and needs become clear. The following themes will play a large part in achieving and managing TBL:

- **Sustainability metrics and management systems.** TBL requires the development of credible sustainability metrics and management systems to maintain a TBL policy system. There have been excellent advances in this area (most focused on environmental sustainability), but there is still no clear vision on what TBL systems would look like or how they could be widely applied and accepted as credible enough to drive major decisions or tradeoff solutions.
- **Public participation.** Under any scenario (the likely exception may be Crisis World), a strong framework for communication, public participation, and outreach will be needed. TBL will require not only communication but also multisector engagement. Transportation agencies will need to consider building a stronger engagement framework around current needs development and planning processes to prepare for the evolution of a TBL policy system.
- **Prioritization and accounting for full costs.** Total cost accounting will be a necessary feature in TBL to support realistic decisions in coming years. In fact, it is already a pressing need for agencies as they consider present-day sustainability investments and project or program risk sharing with the private sector.
- **Culture change.** Agencies will need to facilitate internal culture change from traditional planning and transportation biases and (sometimes narrow) focus on environmental sustainability to TBL as a goal. Internal education, a clarified vision on long-term sustainability (and TBL) objectives, a "code of TBL ethics," and celebration of TBL team and individual behavior may be good ways to begin a general culture change.

CHAPTER 7

Near-Term Tools and Strategies to Consider

Transportation agencies are considering strategies to prepare for a future in which transportation could best support a sustainable TBL policy system. Those strategies depend on understanding the challenges and opportunities to be found in the envisioned TBL policy system and the gaps—where do agencies need to go from here? This chapter recaps the research on where transportation agencies are now in relation to a TBL policy system; the key issues for evolution to a new TBL policy system; followed by what agencies can reasonably do to assess, prepare for, and participate effectively in that evolution.

This research, along with other work (including the other reports in the *NCHRP Report 750* series and *NCHRP Report 708: A Guidebook for Sustainability Performance Measurement for Transportation Agencies*), has assembled and continues to assemble a considerable body of information and opinion to support practical deliberation on the strategies needed. In referring to "transportation agencies" in this discussion, the report addresses a large and variable audience of government agencies at all levels in the transportation community; therefore, not all of the research results will necessarily interest or resonate with the entire audience in the same way. However, it is clear that a viable TBL policy system will require close collaboration and strategic consensus at all levels of government as well as with the private and institutional sectors.

Figure 14 summarizes the policy system evolution spectrum.

The research presented in Chapter 2 and Appendix D of this report suggests that many state transportation agencies have evolved from a Level 1 policy system (Compliant Transportation) to a Level 2 policy system (Green Transportation) over the past decade. The research also suggests that overall, urban local agencies are slightly ahead on this scale and that federal agencies are behind in terms of current capabilities and initiatives.

It is logical that a new transportation policy system related to the environment, with economic and social implications, would emerge and evolve at the local level and would build momentum from there. At the local level, consensus can be developed around a narrower set of specific issues, and land use decisions usually are made or strongly influenced locally. This local influence is not necessarily operative for the development of other policy systems built around other concerns or needs. For example, consider the speed and effect of the policy system built around transportation security following the events of 9/11. Figure 15 is a comparative illustration of the top-down and bottom-up policy system development processes.

The top-down and bottom-up policy development processes are not mutually exclusive. As (and if) momentum builds for sustainable TBL initiatives and as larger investment decisions are needed, a top-down process may play a stronger role.

The following sections present for consideration strategies for moving forward, first at a general level, followed by more function-specific approaches.

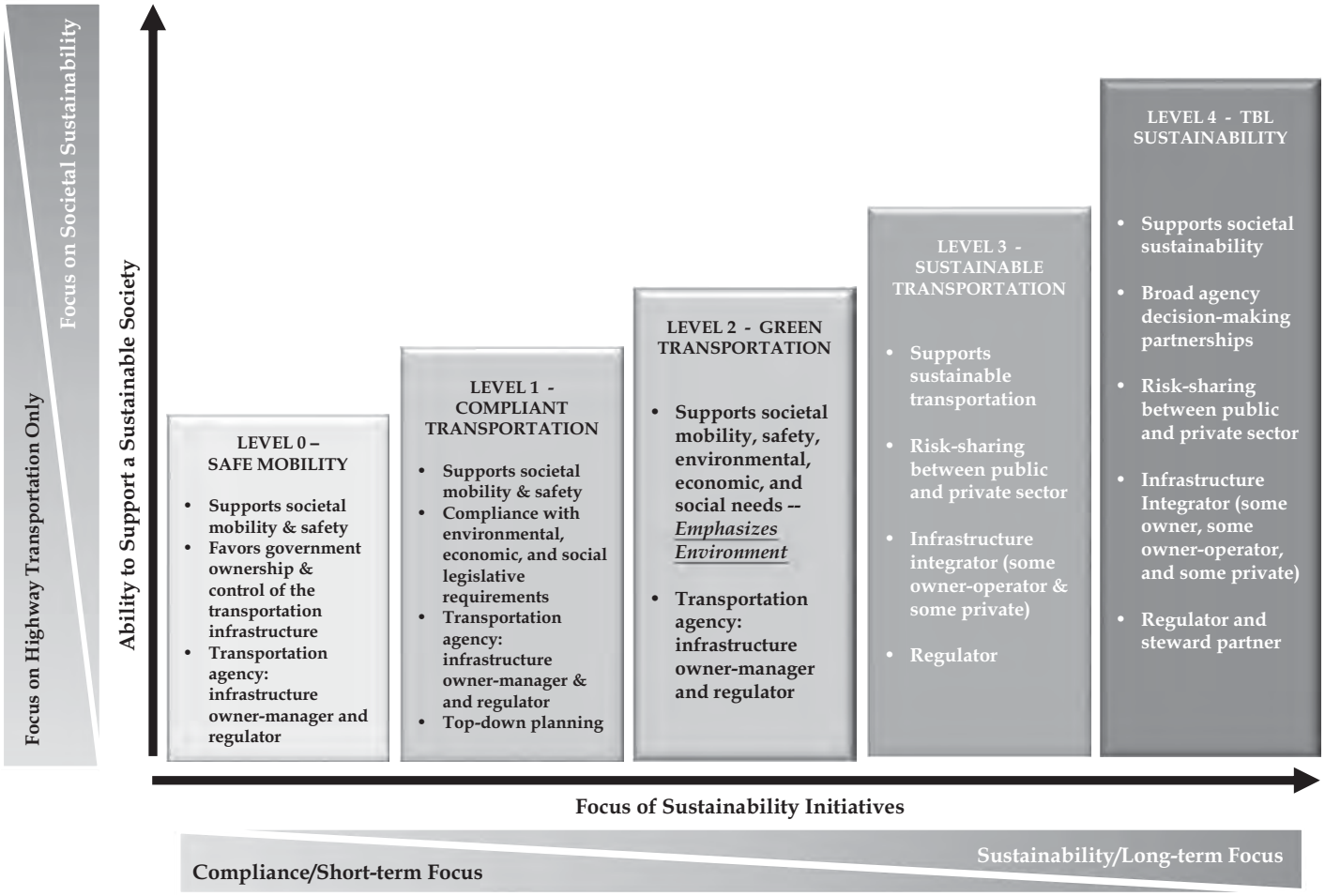


Figure 14. Policy system spectrum related to sustainability capability and initiatives.

7.1 General Strategies

Decisions about investing an agency's focus, funds, and political capital are difficult to make toward what could be a distant objective without careful and continuous assessment of the evolving policy system around sustainable TBL, both regional and national. Although research shows that significant activity and momentum have been building toward green transportation and context-sensitive development, there is no experience with sustainable TBL to conclusively show that it is practicable. For evaluation of program and strategic decisions to invest in sustainability initiatives, decisionmakers need barometers or indicators to assess the evolution of TBL policy systems, the state of the practice in the industry, and a sense of the demand for the initiative. These will assist in supporting decisions on priorities, level of commitment, and potential return on investment (ROI).

The general strategies identified in this section would focus agencies on (1) detecting and assessing the evolution of a sustainable society policy system and (2) assessment and readiness of agencies and the transportation community to support a future TBL policy system.

Some general strategy development actions for agency consideration in the near term (in addition to tracking relevant legislation and rulemaking) include the following:

- Establish or participate in a national dialogue on evolution of a TBL policy system, including all levels of government and the private sector

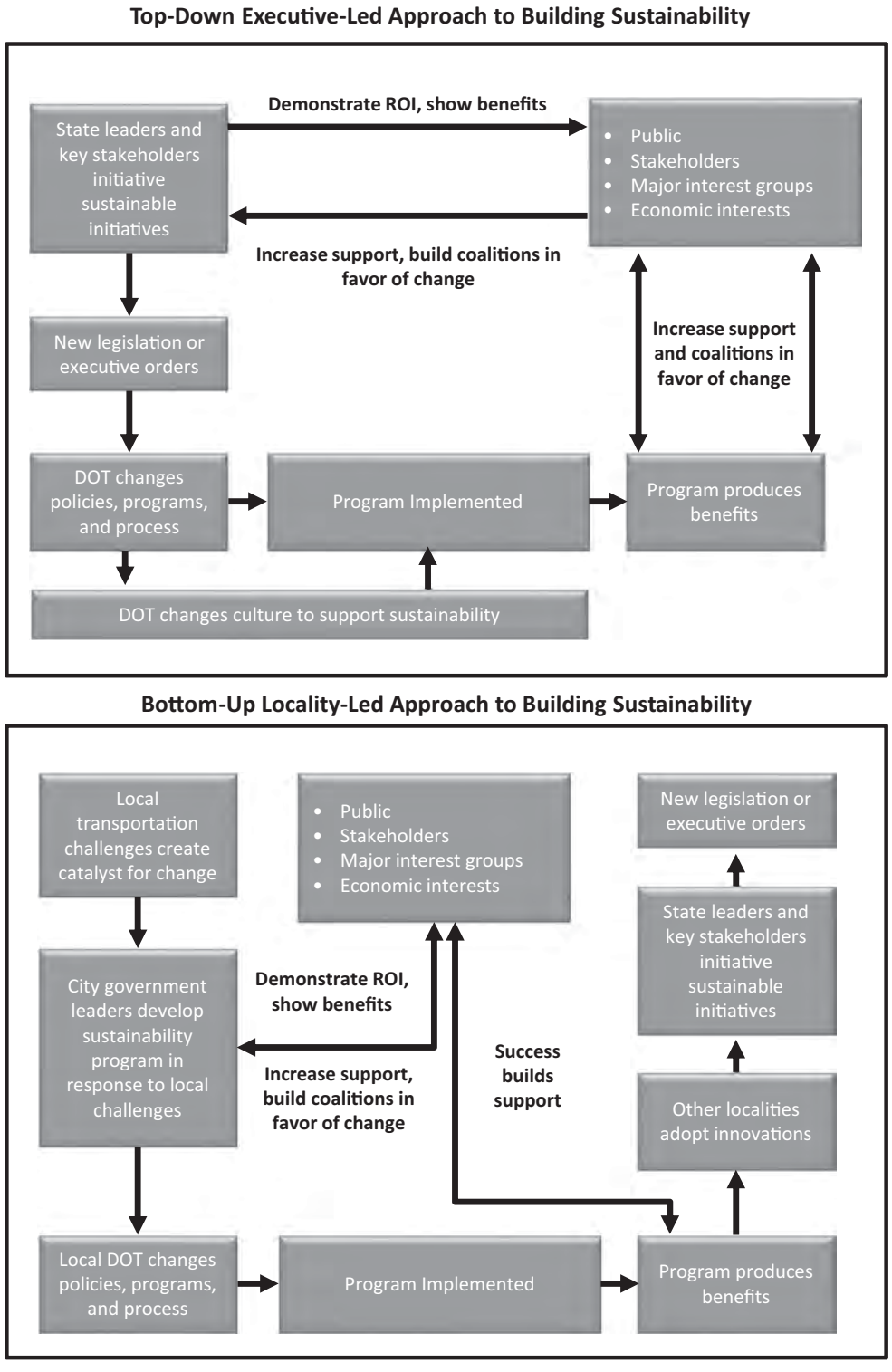


Figure 15. Policy system development—top down, bottom up.

- Monitor and assess the development and spread of sustainability rating systems and measures, particularly those sponsored by independent rating bodies
- Monitor and assess the development and adoption of measurement and certification standards, particularly those that deal with two or more elements of the TBL
- Monitor and assess the deployment of sustainability tools and methods, particularly those adopted by several peer agencies, focusing on those that involve two or more elements of the TBL
- Conduct periodic discussions with stakeholders and agency constituents to take stock of the outlook for sustainable TBL (e.g., timing of such dialogue could be triggered by significant events, rulemaking, or significant trend changes in the factors monitored)

Voluntary adoption and use of measurement and rating standards by agencies and the private sector is a strong indicator of their utility and credibility within the community or market, which is why they are the focus of several of the previously listed monitoring activities. In addition to the aforementioned tools, there are tools and methods that agencies can adapt, develop, and use broadly to support high-level agency functions:

- Self-assessment tools to continuously gauge the "TBL maturity" and capability of the agency to prepare for the next phase of development of the sustainability policy system, which will help focus on near-term actions to improve or strengthen focus, if needed (An example of such a tool is included in Appendix F.)
- Sustainability-related ROI assessment tools, which could support communications and decisionmaking for many agency functions
- Surveys and scans to follow up on previous sustainability initiatives and decisions to confirm or calibrate logic and assumptions

Transportation agencies could implement such actions at relatively low expense. They are easily reversible, "no- or low-regrets" actions that produce strategic information and insights into future demands and benefits.

The following section outlines near-term strategies for considerations related to agency functions and a framework for the research. Where agency initiatives are specifically cited in this report, they are intended to provide examples and information on lessons learned. And since many of those initiatives have developed in recent years, they are not necessarily proven as the "right" approaches for wide acceptance.

7.2 Development of Consensus on Future Vision, Goals, Objectives, and Needs

The general process for this function is currently well established for most state agencies. Several aspects of this process present challenges in dealing with sustainability, particularly when moving out of the discussion on transportation and environment and moving into the discussion of transportation and TBL. The research team suggests that TBL will complicate the following areas:

- Achieving agreement from stakeholders and partners on a definition of sustainability, a definition that is built on TBL and also accounts for state and regional needs and priorities
- Mapping agency goals to the proposed definition of *sustainability*
- Developing associated measurable objectives to track agencies' progress in addressing needs and achieving progress in meeting goals
- Developing performance measures tied to the proposed objectives and for each focus area

These processes likely will become routine when a TBL policy system has developed and matured, when appropriate ROI models and performance measures will presumably exist. An ROI model that can function on a macro level (pre-project planning and selection) could be

useful in the near term to test and incorporate public expectations for TBL outcomes. This challenge is magnified by the need to address the needs of multiple civil agencies as the TBL policy system evolves.

Given that future TBL-related policy systems likely will require much more public, interagency, and intersector engagement than previous decades, agencies may find it useful to test the various choice-facilitation models that already have been developed. These models are interactive and can encourage multiple stakeholders to engage in decisionmaking by analyzing responses to many issues that involve choices, producing weightings, rankings, and other data to facilitate negotiation and consensus.

Summary—Consensus on Needs and Goals

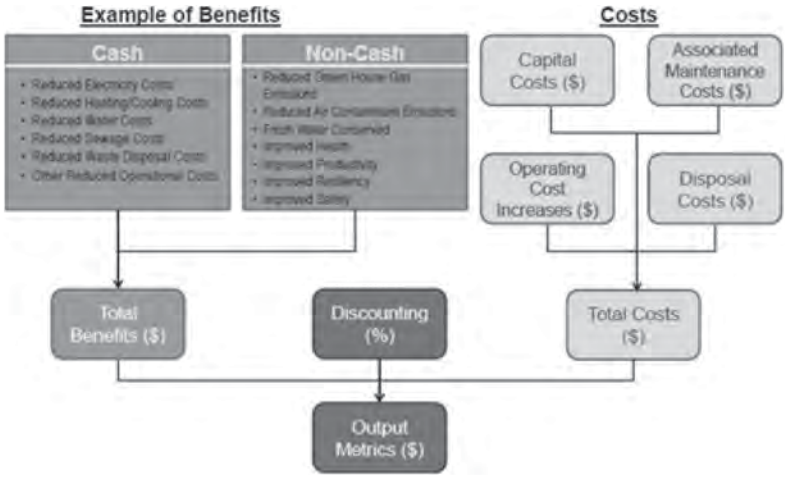
- Reach consensus with stakeholders and partners on a definition of sustainability that is built on TBL and accounts for the needs and priorities of the state and region.
- Map agency goals to the proposed definition on sustainability.
- Develop associated measurable objectives to track agencies' progress in addressing needs and achieving progress in meeting goals.
- Develop performance measures tied to the proposed objectives and each focus area.

7.3 Planning and Programming

Transportation agencies can select from numerous tools to improve sustainability planning and programming. For example, California has developed the Regional Blueprint Planning Program [see Applied Development Economics, Inc. and Collaborative Economics, Inc. (2010)]. The California legislature established this process in 2005 as a 2-year program and has since expanded it. *Regional blueprints* are collaborative planning processes that engage residents of a region in articulating a vision for the long-term future of their region. The regional vision is developed from residents' values and priorities and informed by advanced geographical information system modeling and visualization tools that demonstrate the potential impacts of growth and planning decisions. The process leads to the development of alternative growth scenarios for the region and, through a public process, to selection of a preferred growth scenario that can then guide regional and local land use and transportation decisions for a future that is sustainable while also meeting residents' needs and providing a high quality of life for all.

The California DOT (Caltrans) publishes regular reports on the success and progress of the plan. For example, the 2010 *California Regional Progress Report* presents a framework for measuring sustainability based on 20 integrated, place-based, quality-of-life regional indicators. Regional-scale issues, such as air quality, housing affordability, vehicle miles traveled, and electricity use, form the basis for assessing the combined impact of regional outcomes on the state's sustainability. Data needs are highlighted for important regional-scale indicators that currently lack widespread or accurate measurements, including tracking new development, combined housing and transportation costs, and equity. The report calls for dialogue among state, regional, and local governments to share strategies, address disparities, define sustainability, and improve sustainability measurement.

The planning and programming function is particularly in need of improved ROI tools and approaches for estimating sustainability. These tools can be used to select specific projects and to communicate the business case for sustainability to stakeholders. Many such tools are currently being used in the United States and other countries. There also are a number of firms that have developed these tools and offer them as part of their services (e.g., HDR, PricewaterhouseCooper). For example, HDR has developed a sustainability ROI (SROI) tool. However, the tool is still a



Source: HDR

Figure 16. Overview of structure of HDR's SROI tool.

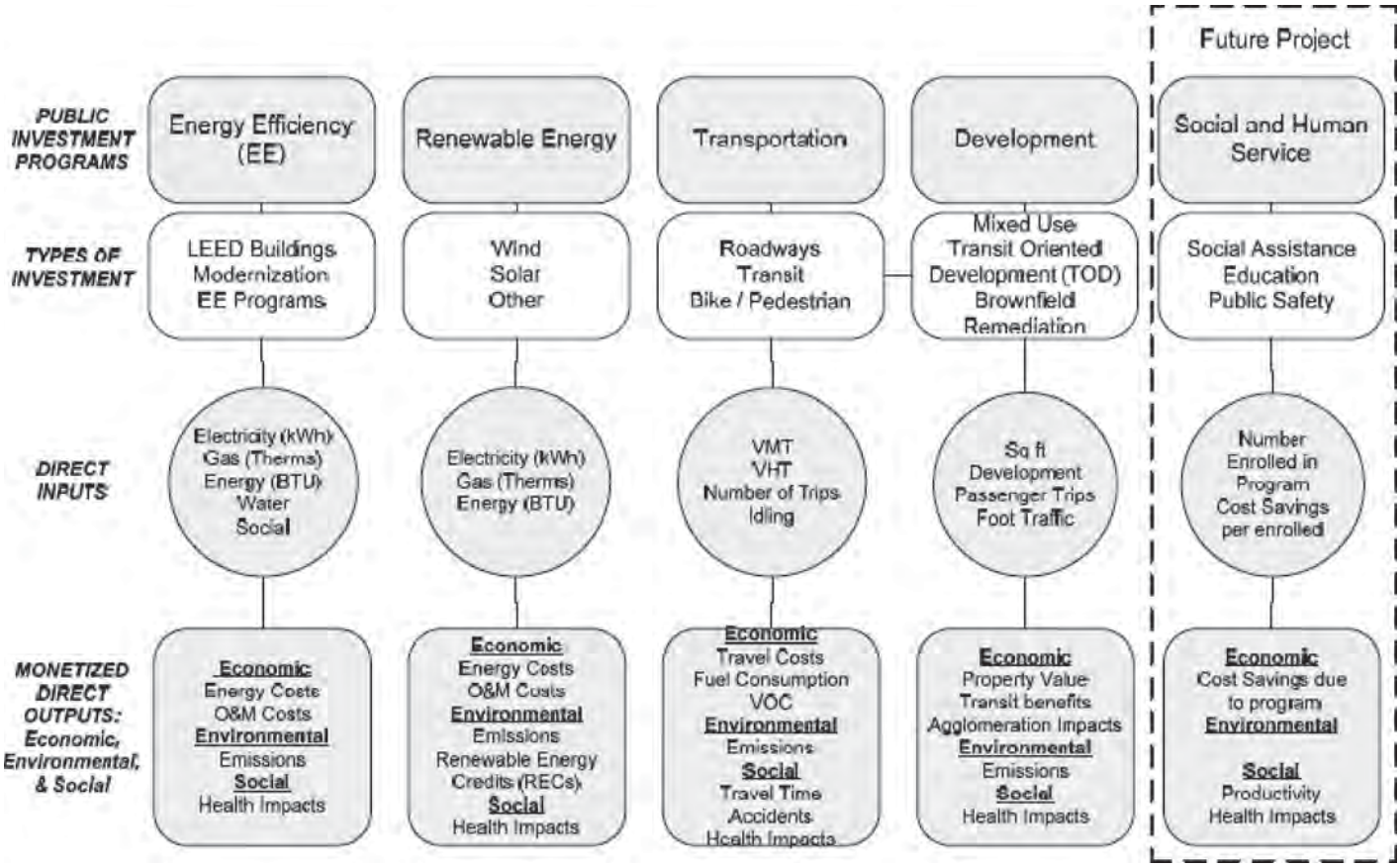
limited version of an SROI model. Figure 16 provides an overview of the structure of HDR's SROI tool.

Several points are apparent from this model. First, the tool is not quite a stand-alone tool. Although at the core of the approach is a Microsoft® Excel model, each application of the approach requires a separate analysis and adaptation of the tool to the specific situation.

Second, the tool is not a transportation-only tool; it has been developed from a variety of infrastructure elements. The very generality of this approach means that the tool is somewhat open ended and flexible to capture numerous potential variables. The tool can be useful to transportation agencies if it is adapted for specific transportation issues of concern. One such example is for the City of Boston's estimates of ROI related to the American Recovery and Reinvestment Act. As can be seen in Figure 17, the system can be adapted for transportation, but needs to be highly customized. In the example, the variables explored are simple and transit related.

Another ROI-related tool is the Parsons Brinckerhoff Regional Impact Scenario Model (PRISM), which is a proprietary transportation economic impact model similar to REMI and other transportation input/output models. PRISM uses documented, established relationships between economic and travel-related factors to generate estimates of regional economic impact. PRISM considers how changes in accessibility—measured as changes in travel time and other transport costs—affect cost efficiency and production (output) for existing industries in a region. PRISM also captures potential improvements in worker productivity and overall labor market activity resulting from personal travel time savings. In addition, PRISM estimates how these initial increases in industry activity and income cycle through the economy in the form of more household and business spending, producing total impacts that can be several times greater than the initial cost savings.

Together, these analyses compose the Regional Economic Impact module of PRISM. This module's focus is on the long-term, permanent changes to a regional economy, as a region's producers and workers become more cost efficient and productive due to better transportation access, and as expanded business sales and personal income recycle throughout the area's economy. Key economic impact measures estimated by PRISM include employment and wage growth, and increases in gross regional (and state) product. Gross regional product (GRP) is equivalent, on a smaller scale, to GDP. It can be viewed as the local economy's GDP—however that local geography may be defined.



Source: HDR

Figure 17. Sample HDR SROI.

PRISM actually consists of several interrelated but separate modules. In addition to the Regional Economic Impact module, it includes a module for conducting an economic benefit-to-cost analysis; a module for estimating impacts on regional employment from a project's construction and maintenance expenditures (in effect, a short-term stimulus impact model); and an SROI module, which considers a range of long-term environmental and social benefits, with a focus on sustainable transportation and development.

The SROI module is intended to help users focus and structure a public dialogue to achieve an enriched understanding of what is really at stake in the consideration of projects, plans, policies, and programs. Specifically, by using information typically contained in environmental analyses, the module uses dollar equivalents and econometric techniques to bring social, economic, and environmental factors onto a level playing field with traditional project costs. Social and environmental factors include carbon dioxide emissions, air quality impacts, water resources, livability, and access to transportation. Techniques used to estimate these impacts include consumer (producer) surplus (i.e., willingness to pay versus price), defensive expenditures (i.e., cost to prevent adverse effects), hedonic pricing (i.e., surrogate valuation such as changes to real estate markets), travel cost (i.e., willingness to pay to travel to location), contingent valuation (i.e., surveys, questionnaires, and interviews), and choice experiments.

Some tools do address these broader effects, such as the New Zealand Transport Agency's *Economic Evaluation Manual* (Volume 2; 2010). Towns and cities throughout New Zealand use this tool to estimate the benefits of sustainable transportation projects. The manual breaks down sustainability benefits into a variety of environmental, economic, and social benefits. Benefits

are estimated based on the mode choice changes, such as reduced congestion, reduced idling, and other changes that are intended to occur as a result of sustainability. Environmental benefits are associated with GHGs, criteria air pollutants, water, and other environmental factors. Social benefits are associated with reduced injuries and accidents; improved health (from encouraging mode use shift to walking and biking); and economic benefits, including benefits associated with the value of time and the value of freight delays. The methodology is supported by several default values that localities use to estimate the monetized benefit of factors such as reducing congestion. The methodology also includes the facility-based measures discussed previously (e.g., reduction in energy use resulting from facility improvements) and is packaged as a series of spreadsheets for easy analysis.

Tools used in the United States address many similar indicators. For example, Caltrans has maintained a simple ROI spreadsheet model for more than a decade that estimates the costs and benefits of highway projects. This simple tool guides users through the development of cost estimates and also estimates project benefits in terms of time saved from reducing congestion, reduction in accidents (monetized as reduced morbidity and mortality and reduced cost of responding to accidents), and environmental benefits (e.g., GHG reductions) (see Caltrans, 2007). This tool, known as Cal-B/C, has been in use since the early 2000s.

The Economic Analysis Branch of Caltrans routinely conducts life-cycle benefit–cost analysis for proposed state highway and public transit projects. Such analysis is performed using Cal-B/C. Cal-B/C can be used to analyze many types of construction and operational improvement projects, as well as intelligent transportation system (ITS) projects. Transit projects may include new or improved bus services and infrastructure support projects as well as light rail and heavy rail projects.

The application is structured to analyze several types of transportation improvement projects in a corridor where there already exists a highway facility or a transit service (this constitutes the base case in the analysis). Benefits are calculated for existing and (optionally) for induced traffic, as well as for any traffic diverted from a parallel highway or transit service. Peak and off-peak benefits are estimated separately. Highway impacts are provided for high-occupancy vehicle (HOV) and non-HOV passenger vehicles and trucks. Highway time savings are based on a speed–congestion relationship. Minimal input data is required because the spreadsheet is populated with many default values suited to California urban and rural applications. Each analysis is based on annual transit person-trips and the representative annual average daily traffic for a highway facility. Values are input for the base case and the proposed improvement alternative. Inputs are factored to peak and off-peak volumes and (for highways) truck volumes. As needed, free-flow speeds, before–after transit trip times, transit vehicle miles and before–after accident data are entered, along with fixed costs and annual costs, on a year-by-year basis. Tools of this kind could be adapted to support or feed SROI tools, and the performance benefit computations could be enhanced and/or monetized to feed into similar benefit–cost models for all three bottom lines.

Other tools also support planning (e.g., HDR's SROI tool) and programming (e.g., Cal-B/C). Better-known examples are summarized in Table 36.

Summary—Planning and Programming

- Expand existing modeling and planning tools to account for multimodal options and impacts, as well as regional quality of life.
- Coordinate data collection activities with engaged partners, including state and local agencies, as well as system operators and the private sector.
- Connect the prioritization process to proposed TBL goals, measures, and objectives, such as ROI estimators, the Economic Assessment of Sustainability Policies of Transport (ESCOT) model (Schade, 2005), and the Assessment of Transportation Strategies (ASTRA) model (Schade et al., 2005).

Table 36. Assessment and rating tools—main focus on planning and programming.

Methods and Tools	Developer/Owner	Description and Use
GreenLITES	New York State DOT	The expanded program includes rating systems, spreadsheets, and other metrics to assess projects, plans, O&M programs, and regional programs.
Smart Mobility Framework (SMF)	Caltrans	The SMF was prepared in partnership with the U.S. EPA and various California state government offices to address both long-range challenges and short-term pragmatic actions to implement multimodal and sustainable transportation strategies in California. The SMF planning tool helps guide and assess how well plans, programs, and projects meet a definition of *smart mobility*. Smart Mobility 2010 provides tools and techniques that improve transportation by using the SMF principles to achieve sustainable outcomes.
Least Cost Planning	Oregon DOT	Model for use as a decisionmaking 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	Maryland State Highway Administration	The tool employs a spreadsheet with six categories of sustainability indicators: mobility, safety, socioeconomic impact, natural resources, energy and emissions, and cost. Includes more than 30 sustainability performance measures.
Project Assessment Tool	State of Rhode Island	The tool includes the following five categories: (1) transportation choice and accessibility, (2) housing choice and affordability, (3) economic development, (4) support of existing communities and designated growth centers, and (5) community character and collaboration. Most categories contain five to six questions. Weighting is available but not required.
Sustainability Enhancement Tool	Texas DOT	This spreadsheet-based calculator applies performance measures for sustainability at the highway corridor level; it includes 12 performance measures.
Infrastructure Voluntary Evaluation Sustainability Tool (INVEST)	U.S. DOT, FHWA	INVEST was developed by the FHWA as a practical, web-based collection of voluntary best practices, called "criteria," designed to help transportation agencies integrate sustainability into their programs (policies, processes, procedures, and practices) and projects.
Composite Sustainability Index	Atlanta, Georgia	Considers multidimensional conflicting criteria in the transportation planning process and identifies the most sustainable (or least unsustainable) plan for predetermined objectives.
Sustainable Transportation Access Rating System (STARS)	North American Sustainable Transportation Council (a collaboration of public- and private-sector professionals from Oregon, Washington, California, and Nevada)	This framework applies 29 credits organized into seven categories: integrated process, access, climate and energy, ecological function, cost-effectiveness, analysis, and innovation.
Sustainable Corridor Rating System	University of Delaware, Newark	Methodology for rating systems applied to urban corridors.

(continued on next page)

Table 36. (Continued).

Methods and Tools	Developer/Owner	Description and Use
Evaluative and Logical Approach to Sustainable Transport Indicator Compilation	U.K. government	This framework is for identifying and selecting a small subset of sustainable transport indicators.
Green Guide for Roads	Transportation Association of Canada	The initial framework includes 13 areas where sustainability practices can be applied, with a description of requirements and associated best practices or strategies. It 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.

7.4 Budgeting and Resource Allocation

Looking forward, budgeting and resource allocation functions may need to undergo changes to accommodate new business models that require greater flexibility to enable transfers and shifts of budgets across agency organizational units and among agencies as decisions and risks are shared to a greater extent than today. However, such changes likely will occur only after new business models are developed; no specific changes in typical agency budgeting processes have been identified as needed for the near term.

Total cost accounting (TCA) is needed for TBL analyses to capture the full cost and range of all impacts. Understanding the full scope of costs and attendant benefits would enable decisionmakers to fully assess the TBL implications of policy and investment decisions. TCA is not likely to serve as a business accounting system, as it would then have to follow rules so prescriptive and consistently applied, that it would not suit its basic purpose—which is to support decisionmaking and priority choices, many of which will involve unique assumptions. TCA is an estimating tool that is intended to account for the most complete possible picture of the costs and benefits of service, product, or system process decisions. TCA operates in economic terms and can incorporate such considerations as life-cycle effects, opportunity costs, and time value of money (or equivalent units of measure). Research indicates that TCA estimating principles in combination with basic economic theory can be applied to nonmonetary value measures such as environmental impact to assess long-term implications of actions on environmental conditions.

TCA can and likely will play a significant part in TBL decisionmaking on major initiatives and programs. To the extent it does, its influence will permeate implementing organizations just like project or program cost–benefit assumptions tend to set the tone and expectations for implementation today. For budgeting and resource allocation functions, the use of TCA would clarify and facilitate translation of policy objectives and outcome expectations along with the funds to be allocated [see also Gibran and Sekwat (2009)].

TCA, or as it is sometimes also called (when applied to sustainability issues) "environmental full cost accounting" (EFCA), is an accounting approach that attempts to estimate the full direct and indirect costs of a proposed project or investment throughout the life cycle. At its most ambitious, TCA attempts to estimate all the costs associated with the TBL arising from the investment. The International Organization for Standardization (ISO) has several accredited

standards useful in EFCA or TCA including for greenhouse gases, the ISO 26000 series for corporate social responsibility, and the ISO 19011 standard for audits.

Specifically, TCA differs from traditional accounting and cost approaches by:

- **Accounting for costs rather than outlays:** Traditional costing simply looks at the outlay or initial expenditure on each budget item. TCA estimates the full cost of the purchase including its impact on other operations or parts of the project and the lifetime cost of the purchase decision.
- **Accounting for hidden costs and externalities:** All purchases of goods and services have externalities and hidden costs. For example, the purchase of a particular vehicle for a transit fleet comes with a set of externalities concerning its production, delivery, and operations and the costs and TBL impact of maintenance operations. TCA attempts to account for all of these hidden costs and/or externalities.
- **Accounting for overhead and indirect costs:** TCA accounts for and attempt to allocate all overhead and indirect costs, including those that are shared with other public agencies. Overhead and indirect costs might include legal services, administrative support, data processing, billing, and purchasing. Environmental costs include the full range of costs throughout the life cycle of a product or delivered service.
- **Accounting for past and future outlays:** Past and future cash outlays often do not appear on annual budgets under cash accounting systems. Past costs are initial investments necessary to implement services such as the acquisition of vehicles, equipment, or facilities. Future (or back-end) outlays are costs incurred to complete operations such as facility closure and post-closure care, equipment retirement, and post-employment health and retirement benefits. TCA attempts to capture all these costs.

The TBL policy system also may affect budgeting and resource allocation by creating the need to make longer-term financial and risk-taking commitments in partnership with other agencies. Both budgeting and resource allocation must be in step with regular funding authorization cycles today. Although those cycles may or may not change in the future, the budget accounting and allocation systems will need rules and processes that allow for recognition and accounting of budget surpluses and deficits that can reasonably be contained and controlled, because funding will fluctuate. Agencies can benefit quickly from TCA by virtue of improved cost tradeoff information, but the need for longer-term budgeting and management of surpluses and deficits, although likely, is not as urgent.

TCA also will improve agency practice by applying one of the key methodologies needed to support sustainability—life-cycle cost accounting (LCCA)—to better estimate the long-term cost of alternative investments. LCCA is a cost-estimating technique for assisting practitioners in determining the costs of alternative investment options for a specific project or projects. LCCA is commonly applied to examine new projects and to assess preservation, rehabilitation, or replacement options for existing transportation assets. LCCA includes initial cost but considers all agency costs and can be expanded to account for user costs throughout the life cycle of alternative projects. LCCA is supported by readily available software and can be adapted to include monetized estimates of "cost" for impacts that are otherwise qualitative.

In general applications, LCCA typically uses discounting to convert anticipated future costs to present value for alternatives analyses. Note that there is a debate over logic and policy issues with discounting. When public funds are used, it is difficult to assess the real opportunity cost incurred (or the discount rate needed).

The FHWA has provided substantial information on LCCA for more than 10 years [see FHWA (2013)]. For example, in 1998, the FHWA produced Demonstration Project 115, "Life-Cycle Cost Analysis in Pavement Design," which developed a technical bulletin, an LCCA instructional

workshop, and a proof of concept for an LCCA software tool. FHWA Resource Center personnel have presented this workshop to more than 40 states.

The FHWA's sustainability guidebook provides numerous examples of cases where states have successfully used LCCA as part of their sustainability programs (Amekudzi et al., 2011). For example, the Illinois DOT's LCCA process evaluates alternatives based on the present worth of future capital, maintenance, and operations costs, which enables the agency to compare alternatives that may incur costs at different times during their life cycles. It also incorporates the interest rate, which is an important consideration in determining discount rates. LCCA helps identify the best value for investment expenditures (i.e., the lowest long-term cost that satisfies the performance objective).

The FHWA's guidebook on sustainability recommends adapting the LCCA methodology to aid in assessing sustainability. Using this approach, the costs of a proposed project are expanded to consider all of the environmental, economic, and social impacts. The decisionmaker can then see the full cost profile of all alternatives and select the alternative with the lowest overall social, economic, and environmental cost. The LCCA methodology, combined with the ROI estimation techniques identified previously, would form a powerful tool for long-term sustainability analysis.

Summary—Budgeting and Resource Allocation

- Increase flexibility in budgeting, which may be needed to support risk sharing within and between agencies over multiple budget cycles. Agencies should consider long-term budget accounting and management and control of reserve accounts.
- Consider the institution of TCA.
- Consider integrating LCCA tools in the planning and budgeting processes.

7.5 Rulemaking and Regulation

Rulemaking by its nature is generally a prescriptive and arduous process. After authorizing legislation is passed, designated agencies are responsible for rulemaking to create regulations, standards for compliance, and regulatory processes. These are vetted with stakeholders through a structured public comment–resolution process.

If the current policy system for transportation evolves toward sustainable TBL, it is inevitable that various forms of legislation will accompany or drive the transition, and the resulting rulemaking can be expected to be complex in terms of the agencies, sectors, scientific content, standards, and process issues that are involved. Throughout the rulemaking process, transportation agencies, other involved agencies, and the private sector will undoubtedly be concerned about their capabilities to comply and about their costs of performing the business of government and the business of commerce.

As the debate over GHG regulation continues, a similar level of concern from the government and private sectors is apparent. But, despite the challenging scientific issues and the practical concerns over how this regulation can work, there is a widely held public opinion and fear that GHG is a major driver of climate change trends. It seems clear to many that action is needed to avert serious environmental problems. Partly as a result of this public dilemma, several major companies and agencies have been measuring and rating GHG output, carbon footprint, and related factors. This is an example of trying to stay ahead of regulation and preparing for legislation or rulemaking to occur.

Under the TBL policy system, it is logical to expect a bias in favor of flexible regulations and voluntary compliance with accepted standards as an important component of successful

sustainable TBL programs. Without this flexibility, rulemaking can be expected to be an onerous task and the rules can be expected to be difficult to comply with. Returning to the GHG example, if voluntary efforts and market effects coalesce into widely accepted guidelines, practical standards of achievement and measures, and rating systems, rulemaking could support or adopt them in a practical form.

Recommendations for agency consideration in this section closely follow the general strategies outlined in Section 7.1, which is to engage in developing methods, standards, and measures for TBL and to test those methods for practicality under the agency's specific functional structure and operating environment. This process can include evaluating, testing, and possibly integrating various approaches already in use (e.g., Caltrans, HDR, and New Zealand Planning Support).

Anticipating and preparing for TBL rulemaking likely will require a holistic approach and viewpoint that represents more than one agency's operating regime. The strategy will need to include and encourage partnering with other agencies, public interests, and experts—the regional and local stakeholders and key actors in the TBL. Wide acceptance and adoption of standards and measures is also known to have led to a form of "self-regulation" for an industry sector if sound value propositions exist for doing so. Suggested near-term focus areas for this process include the following:

- Common understanding of shared concerns, issues, and opportunities connected with TBL
- Overall ROI for the participants in the collaborative effort (i.e., What is the benefit for each party and for all parties? What is the potential cost and risk of not acting?)
- Monetize the impacts of potential regulatory requirements
- Connect impacts to jobs, commerce, and state and local revenues
- High-level TBL-related planning and decisionmaking concepts
- TBL-related viewpoints, standards, and expectations
- TBL-related measures
- Measures of success and rating
- TBL acceptance and adoption issues.

Engaging the transportation community in this way would no doubt present many challenges and would require significant investment of participants' time and resources as well as focus away from other, short-range priorities. However, the sustainable TBL policy system may not be too far off in the future in some regions. In many respects, the "strong" TBL policy system is already in evidence in a number of areas. The expanded Green Leadership in Transportation and Environmental Sustainability (GreenLITES) and the Illinois—Livable and Sustainable Transportation (I-LAST™) examples (see Section 7.6) reflect some of the TBL dimensions and the kind of private–public-sector collaboration needed.

Summary—Rulemaking and Regulation

- Anticipate and prepare for new TBL-related rulemaking activities by, for example, initiating capture of data and measures likely to be required under new regulations.
- Obtain a common understanding of the shared concerns, issues, and opportunities connected with TBL.
- Determine overall ROI (the value proposition) for the participants in the collaborative effort (e.g., What is the benefit for each party and for all parties? What is the potential cost and risk of not acting?).
- Monetize the impacts of potential regulatory requirements.
- Connect impacts to jobs, commerce, and state/local revenues.
- Develop high-level TBL-related planning and decisionmaking concepts.
- Obtain TBL-related viewpoints, standards, and expectations.

- Craft TBL-related measures.
- Determine measures of success and rating.
- Assess acceptance and adoption barriers and issues.

7.6 Service and Project Delivery

Service and product delivery includes all functions and activities that are related to the provision of transportation services and products, including development, design, construction, operations, traffic management, maintenance, and preservation. One of the major issues stakeholders identified was the need for standards and approaches to identify sustainable options and to ensure that the selected materials or systems purchased meet sustainable requirements.

There are several standards-based systems for transportation developments that transportation agencies could use in the near term. For example, in 2011, TRB published *NCHRP Report 708*, a comprehensive analysis of current sustainability rating and performance systems. The report provided state DOTs with a practical and easy-to-use approach to identifying and applying sustainability-related performance measures to transportation decisionmaking and provided a reference compendium of performance measures (Zietsman et al., 2011). In addition, numerous states, localities, and federal agencies have launched efforts to develop, catalogue, and assess sustainability rating systems. Table 37 shows several of these tools and approaches for assessing

Table 37. Assessment and rating tools—main focus on project delivery.

Methods and Tools	Developer/Owner	Description and Use
Guide to Sustainable Transportation Performance Measures	U.S. EPA	Overview of recommended performance measures and a guide to sustainability decisionmaking.
INVEST	FHWA	Web-based self-evaluation tool with three modules: project development, O&M, and system planning; assigns each practice a point value (weight) according to its relative impact on sustainability.
GreenLITES	New York State DOT	The expanded program includes rating systems, spreadsheets, and other metrics to assess projects, plans, O&M programs, and regional programs.
I-LAST	Illinois DOT	A 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.
CEEQUAL International	U.K. government Institution of Civil Engineers	This online assessment tool scores project performance on management and a range of environmental and social issues.
Envision™	Institute for Sustainable Infrastructure (ISI; founded by the American Society of Civil Engineers, American Public Works Association, and American Council of Engineering Companies)	Evaluates, grades, and gives recognition to the community, environmental, and economic benefits of infrastructure projects.
Greenroads	Greenroads Foundation	Project-based sustainability rating system; the performance metric awards points for more sustainable practices during the design and construction phases of roadway projects.

sustainability. Rating and performance measurement tools are rapidly being developed and new tools are being developed and modified all the time.

Green Leadership in Transportation and Environmental Sustainability

One of the most well-known systems is GreenLITES, a transportation certification program developed by the New York State DOT (NYSDOT). GreenLITES is intended to do the following:

- Recognize and increase the awareness of the sustainable methods and practices NYSDOT already incorporates into its project designs and daily operations
- Expand the use of these and other innovative alternatives that will contribute to improving transportation sustainability

GreenLITES is a self-certification program that distinguishes transportation projects and operations based on the extent to which they incorporate sustainable choices. GreenLITES address all stages of transportation projects including planning, maintenance, and operations. Currently, it is primarily an internal management program for NYSDOT to measure its performance, recognize good practices, and identify where improvement is needed. It also provides the agency with a way to demonstrate to the public how it is advancing sustainable practices. NYSDOT project designs and operations are evaluated for sustainable practices, and—based on the total credits received—an appropriate certification level is assigned. The rating system recognizes varying certification levels, with the highest level going to designs and operational teams that clearly advance the state of sustainable transportation solutions.

NYSDOT began the design certification program by evaluating projects that had Plans, Specifications, and Estimates submitted after September 25, 2008. The certification program is modeled after the U.S. Green Building Council's LEED program and the Greenroads Foundation's Greenroads program. NYSDOT's certification program builds on other environmental initiatives already taken by the agency and is part of a long-term program to encourage sustainable choices. The certification portion of the program is designed to be flexible, and to recognize and add new best practices and innovations as they emerge. NYSDOT continues to expand its suite of sustainability tools and to build sustainability into its programs and policies.

Illinois—Livable and Sustainable Transportation

Similarly, the Joint Sustainability Group of the Illinois DOT, the American Council of Engineering Companies–Illinois (ACEC-Illinois), and the Illinois Road and Transportation Builders Association (IRTBA) developed a voluntary system, I-LAST. The *I-LAST Rating System and Guide* (issued January 2010) describes sustainability in terms of transportation and provides a tool for identifying and documenting sustainable practices on highway projects in the state. Specifically, I-LAST does the following:

- Provides a comprehensive list of practices that have the potential to bring sustainable results to highway projects
- Establishes a simple and efficient method for evaluating transportation projects with respect to livability, sustainability, and their effect on the natural environment
- Records and recognizes the use of sustainable practices in the transportation industry

I-LAST identifies the following goals for sustainable projects:

- Minimize impacts on environmental resources
- Minimize consumption of material resources
- Minimize energy consumption
- Preserve or enhance the historic, scenic, and aesthetic context of a highway project

- Integrate highway projects into the community in a way that helps to preserve and enhance community life
- Encourage community involvement in the transportation planning process
- Encourage integration of nonmotorized means of transportation into a highway project
- Find a balance between what is important to the transportation function of the facility, to the community, and to the natural environment and what is economically sound
- Encourage the use of new and innovative approaches in achieving these goals

I-LAST includes a checklist-based scorecard for evaluating the sustainable practices included in a highway project, with 17 separate sustainable features in eight categories:

- **Planning:** context-sensitive solutions, land use, community planning
- **Design:** alignment selection, context-sensitive design
- **Environmental:** protection, enhancement, or restoration of wildlife communities; protection, enhancement, or restoration of native plant communities; noise abatement
- **Water:** reduction of impervious area; stormwater treatment; construction practices to protect water quality
- **Transportation:** traffic operations; transit; improvement of bicycle and pedestrian facilities
- **Lighting:** reduction of electrical consumption and stray light
- **Materials:** use of environmentally benign or low-impact materials and/or environmental sound demolition, disposal, and construction techniques
- **Innovation:** use of experimental feature(s) to improve the sustainability of a project

For each of the sustainability features, the scorecard lists activities and the points that can be earned for each activity included on a project. It also provides an explanation and lists resources to help users better understand how to implement each of the sustainable features.

These examples also show how rating and measurement systems can influence agency and private-sector behavior toward TBL principles. Various rating approaches are used to influence contract selection decisions, TBL-sensitive project development, and delivery.

Infrastructure Voluntary Evaluation Sustainability Tool

The FHWA recently developed INVEST, a web-based tool that contains a collection of sustainability best practices, referred to as "criteria" in the tool, that are intended to help transportation practitioners measure sustainability in highway projects. INVEST is focused on sustainable highways rather than the broader subject of sustainable transportation. The purpose of INVEST is to identify these criteria, to assist organizations in researching and applying these criteria, and to establish an evaluation method to measure the benefits and progress of sustainable highway projects.

The FHWA launched INVEST 1.0 in October of 2012. The tool was pilot tested across the country in 2011 and improved to reflect lessons learned. It also benefited from input by industry associations such as AASHTO and the American Society of Civil Engineers (ASCE).

The tool includes six different scorecards for the evaluation of project development based on type of project (basic, extended, paving only, or custom) and location (urban or rural). Scorecards are also available for operations and maintenance programs, and system planning and processes. By offering transportation agencies a collection of best practices, INVEST serves two purposes. First, it helps identify workable solutions that allow agencies to incorporate sustainability into their transportation projects or programs. And, second, it gives them a tool for measuring their progress. DOTs or MPOs can use the results of an INVEST evaluation to support implementation of sustainable practices in pending planning or project decisions or to identify potential changes to business processes.

Version 1.0 of INVEST includes weighting for the project development criteria only. Criteria in the system planning and operations and maintenance modules are all equally weighted at 15 points (except the bonus criterion in system planning, which is valued at 10 points). A list of the criteria in each module is included in Section 8.1.1. The following paragraphs discuss the weighting of project development criteria.

The overall goal of weighting is to make the point value for each criterion commensurate with its potential to affect sustainability both in terms of significance and duration of the impact.

When using a set of criteria to evaluate performance toward meeting a goal, a key question is the extent to which the criteria are equally important in meeting that goal. If the criteria are of unequal importance, the measures of success can be improved by weighting the relative importance of the criteria. When assigning weights, the contribution to sustainability achieved from the worst likely outcome to the best likely outcome for one criterion should be compared to another. In other words, larger weights are assigned to criteria that are likely to have the largest impact on sustainability from project to project.

As an example, envision two projects: one in which best-in-class environmental training is provided versus another where no environmental training is provided. The difference in sustainability likely to occur from that criterion is likely to be small (because training does not necessarily result in action), thus that criterion should be assigned a relatively low weight. Now envision two other projects: one in which best-in-class long-life pavements are designed and implemented and another in which they are not. Here the difference in sustainability associated with that criterion is likely to be substantial due to the cumulative benefits achieved over the project life cycle. Therefore, that criterion should be assigned a relatively high weight.

INVEST can also be used to score a project based on total points achieved. A score is one measure of sustainability at one point in time. It reflects the number of sustainability best practices included and their relative impact on sustainability. INVEST can be used in a number of ways, including as a planning tool, a decisionmaking tool, and an evaluation tool. The user can choose to what extent to measure success against the absolute scale of how many overall points are achieved by a given program. INVEST may be used to score a program based on total points achieved. At this early point in its development, the tool contains rough estimations of the different achievement levels (including bronze, silver, gold, and platinum). Because INVEST is not based on third-party validation of scores or certifications, scores are not considered recognition by the FHWA that a program has met the achievement level of sustainability but rather recognition that the users have self-evaluated their program and met the indicated achievement level.

Summary—Service and Project Delivery

- Adopt standards and approaches to identify sustainable options and ensure selected materials or systems purchased meet sustainable requirements (as defined in the development of goals, objectives, and associated performance measures).
- Consider embedding sustainability/TBL-related ratings and standards into operational activities related to provision of transportation services, products, and infrastructure—including development, design, construction, operations, traffic management, maintenance, and preservation.

7.7 Education and Cultural Development

Interviews with stakeholders reveal a broad consensus that sustainability will require substantial cultural change within agencies, the private sector, and the public sector. In the current fiscal and economic climate, many agencies lack the resources and support to engage in broad new initiatives. In

general, stakeholders believe it will be helpful to promote sustainability as an economy measure and as a more efficient means of delivering service. In particular, a change in the mindset is needed away from focusing on the traditional level of service (LOS) and on transportation as an end in itself to focusing on how transportation can improve community life and meet community needs. Stakeholders expressed a need for new, more holistic ROI tools that help to support and clarify the business case for sustainability, and to communicate the value of sustainability as a common-benefit initiative.

Sustainable TBL is expected to require a new decisionmaking paradigm to manage TBL-sensitive transportation decisions across multiple modes and jurisdictions. Several states recently have embarked on bold initiatives to change the culture of DOTs away from the traditional LOS bias. These initiatives can serve as a model for how DOTs can move to greater support for sustainability. For example, in response to a perceived lack of confidence from stakeholders, limited funding, loss of knowledgeable employees, and a push from policy makers to outsource, the Louisiana Department of Transportation and Development initiated a major program of culture change (Bridges, 2008). It adopted a two-prong approach. First, it developed tools to demonstrate the ROI of any proposed change and carefully identified the changes that really would produce a difference in performance and service delivery. Second, it engaged the department head as the chief sponsor of the initiative. The chief sponsor communicated forcefully that this was a "change-or-die" situation and that it required maximum commitment. Multiple communications initiatives were launched to demonstrate the need for change, explain the rationale and proposed changes, and explain how people could be part of the change. The program focused on quick-wins, claiming low-hanging fruit, and building momentum for change (Bridges, 2008).

Some governments have attempted to initiate development of a new culture through extensive public participation programs. The City of Perth, Australia, for example, in 2003, began a broad-based consultation process to create a new vision of the city. This process brought together more than 42 government departments and citizens and business groups to create a vision of Perth in 2030. As part of this exercise, a survey was conducted of more than 1,700 households, and a 1-day planning forum was held with more than 1,000 participants. At that forum, participants were broken down into 10-person teams, each given a particular transportation problem. Each team had to identify solutions and wrestle with the tradeoffs that planners face between sustainability, mobility, and economic growth. The result was a consensus plan known as "Network City," which was widely supported and endorsed by all major interests and has as a goal that 60 percent of all new infrastructure and private construction be developed as car-free, sustainable networks (Schiller et al., 2010).

Summary—Education and Cultural Development

- Consider the development of a sustainability code of ethics for the agency that focuses on supporting a sustainable society.
- Develop and conduct training activities with internal staff on incorporating sustainability principles in transportation decisionmaking processes.
- Set employee initiative and performance incentives associated with sustainability.
- Set up and maintain an internal news forum and discussion on sustainable TBL.
- Support the development of sustainability-related coursework in regional education institutions, and encourage/support study by agency personnel.

7.8 Outreach and Communications

Responsibility for supporting, planning, and executing sustainable TBL will likely extend beyond the traditional jurisdictional and modal organizational boundaries of national, state, and local transportation agencies—because TBL policymaking and resource decisions will

involve coordinated selection and execution of strategies by agencies and entities focused on all three bottom lines. Transportation will likely be called on to support and participate in policy (and possibly funding) decisions directly related to all three bottom lines as well. As authorities and TBL planning and management process requirements are gradually developed, the agency and interagency "lines and boxes" will emerge based on specific needs for oversight, decision-making, execution, and compliance. Existing agency roles and functions would necessarily continue, but TBL management could take a matrix form, cutting across not only internal organizational units but also across multiple external agencies. Private- and public-sector entities could jointly occupy points in that management matrix.

As (and if) a TBL policy system evolves in the future, agencies that have acted to establish the needed external decisionmaking lines of communication and processes will be best prepared to transition to a more holistic funding and management approach to transportation services.

In the meantime, agencies could examine these relationships and gain practical insight by establishing TBL-related coordination and communication processes, both within and outside existing organizational boundaries.

Outreach

- **Consider establishing interagency coordination on TBL.** Several interviewees noted that sustainability appears to be a top-down-driven process. However, most land use and transportation decisions are made at the regional and local levels, and, as indicated earlier, sustainability initiatives make it evident that there is an important bottom-up process in motion. Federal government and state agencies, MPOs, counties, municipalities, and modal agencies all would play significant roles in managing TBL. Establishing a coordination model with these entities could be an effective way to establish an overarching set of acceptable TBL goals and to execute TBL-related planning and decisionmaking functions across a region.
- **Establish intra-agency coordination.** Sustainability applies to every stage of decisionmaking: planning, design, and implementation of projects and infrastructure as well as day-to-day O&M. All interviewees noted that addressing sustainability does not fit neatly into their existing organizational structures. Agencies may consider establishing and chartering a cross-cutting team or teams to coordinate activities supporting sustainability within the agency. Such teams also could play a significant role in developing the interagency linkages needed.

Communication

- Most stakeholders agree that better and ongoing communication is needed to describe an agency's progress in achieving sustainability goals, objectives, and policies.
- Transportation agencies must communicate with internal and external stakeholders about TBL through transparent indices, numbers, tables, graphs, scorecards, dashboards, and other information formats.
- Communications on TBL-related issues would be most productive at this stage of TBL evolution as a two-way process engaging a broad set of stakeholders—focused primarily on decision-makers and thought leaders, including public-sector representatives; trade and professional organizations; federal, state, and local agencies; and the private sector. The Florida DOT's Corridor of the Future program provides useful practical experience for such an effort (Lee, n.d.).

Summary—Outreach and Communications

- Establish interagency and intra-agency coordination on TBL issues.
- Conduct regular communication and information exchange activities with trade/professional groups, the private sector, and the public.

- Keep outreach and communication activities ahead of the evolution of the transportation policy system.
- Support overall outreach activities with relevant facts and figures as sustainable TBL initiatives progress.

7.9 Summary

The research has shown that the principle gaps between today's policy systems and sustainable TBL are found in the needs development, policymaking, and planning functions of transportation agencies. These functions will need to engage shared objectives and shared risk-taking among many stakeholder agencies in a region as well as private-sector actors. Institutional structures will form slowly as stakeholders grasp the commonality of mission needs and benefits under the TBL system. Tools and methods to inform, assist, and test the TBL concept and assess needed risk sharing between stakeholders will be most useful for agencies in the near term—pending what these tools and methods reveal about the practicality of managing TBL sustainability. It can be seen that many of the potential near-term actions address tools, methods, and TBL assessment framework development.

Some suggestions in this chapter focus on situational assessment, and self-assessment to match real trends with the right agency capabilities to anticipate incremental changes and respond to them. A third category of suggestions deals with outreach, training, and educational programs to build professional capacity and share knowledge for the future.

CHAPTER 8

Sustainability Tools and Methods: Key Directions for Development

A significant body of practical knowledge and opinion has developed in the last few years on sustainability performance measures as well as assessment/rating systems. These measures and rating systems address one or more of the three sustainability bottom lines described throughout this report. Promising progress has been made in this area, as measures and rating approaches are being accepted and more widely applied across industry. Sustainability performance measures and ratings can already inform priorities for agency resource investments and strategic focus on sustainability initiatives. But for *long-term* TBL sustainability planning and decisionmaking, significant TBL measurement and assessment challenges still need to be met.

At the highest level, measuring and rating societal sustainability at regional and national levels remains an art, and mostly a matter of public opinion and a subject of academic study. Governments have focused on policies to reflect perceptions of "greater goods," as well as public opinion and demands regarding the most pressing needs of the era. Available resources are typically divided and directed at the policies, based more or less on the relative costs of implementing each policy. Generational equity is given consideration in relation to entitlement programs and some single-bottom-line objectives but is much more difficult to model and address along TBL dimensions.

At the level of transportation support for TBL and generational equity, models for the *contributions of transportation investments and returns on TBL* are easier concepts to visualize but challenging to develop and implement with current data and available algorithms. Key challenges include the following:

- Quantifying the full life-cycle cost of transportation systems (not necessarily projects)
- Total cost accounting at program levels
- Linking transportation performance and services to economic, environmental, and social bottom lines in simple and data-driven ways
- Valuating future (generational) transportation performance and TBL impact

Transportation agencies are adopting useful tools and methods today that will help agencies prepare for a sustainable future. These include tools and methods that are (1) sustainability rating systems and performance measures; (2) sustainability ROI estimators; and (3) LCCA, life-cycle assessment (LCA), and sustainability cost–benefit analyses of various kinds. As previously discussed, these approaches focus on transportation planning and programming, and project delivery—mainly from within transportation agencies' mission and modal perspectives.

8.1 Sustainability Rating Systems and Performance Measurement Systems

There has been rapid growth in the development of sustainability rating systems, performance measures, and data sources. When research for this report was initiated in 2010, only a few developed performance measurement or rating systems had been initially tested and placed in

regular use, and the data sources for these systems were difficult to identify. However by 2012, more than a dozen sustainability rating and performance measurement systems existed and were being used by various state, local, and regional transportation agencies. In 2011, TRB published *NCHRP Report 708*, a comprehensive analysis of current sustainability rating and performance systems. The report provided state DOTs with a practical and easy-to-use approach to identify and apply sustainability-related performance measures to transportation decisionmaking and provided a reference compendium of performance measures (Zietsman et al., 2011). In addition, numerous states, localities, and federal agencies have launched efforts to develop, catalogue, and assess sustainability rating systems.

Analyzing the current state of the practice of these tools and methods, several common characteristics and issues are notable, specifically:

- Growing consensus among transportation agencies on measures to be applied in sustainability rating systems
- Third-party-scoring versus self-scoring approaches
- Challenges in incorporation of multiple modes
- Lack of effective treatment of intergenerational equity issues
- Rating of agency maturity in sustainability practices and functions

8.1.1 Growing Consensus on Sustainability Ratings and Measures

In general, most sustainability performance measurement and rating systems accept the concept of the TBL to various degrees. The rating systems include measures or qualitative indicators relating to environmental protection, such as changes in emissions, reductions in the use of hazardous materials in construction, and increased use of recyclables, and many others. Similarly, many systems use conventional transportation metrics, such as maintenance of functionality during improvements, improvements in safety, or other related metrics. In terms of social well-being or civic measures, performance rating and measurement systems focus on social equity issues or the preservation of resources of community or cultural value. All this suggests a growing convergence of systems and approaches to thinking about sustainability. Most rating assessment approaches found in the research reflect and adapt useful rating approaches from other agencies' initiatives and usually begin with an initial analysis by the sponsoring agency of existing systems, tailoring and adjusting them to specific agency needs, terminology, and functions. As indicated in Chapter 7, most sustainability assessment tools focus project assessment and support on either the planning and programming function or the project delivery processes.

As an example of more recent rating system development, the FHWA began developing a highway sustainability rating system (INVEST) to recommend for general application in the industry. The research and concept incorporated ideas from numerous sustainability rating systems and guidelines developed by state and local transportation agencies. For INVEST, best practices were identified and incorporated from more than 20 other systems. The methodology draws directly on insights from ISI's rating system Envision, GreenLITES, Sustainable Sites, Greenroads, and I-LAST. In addition, further INVEST development is intended to be continuously updated and augmented to incorporate emerging best practices and stakeholder inputs—and to coordinate with several sponsors for other ratings systems, including ISI's activities to define ratings criteria and standards (FHWA, n.d.). Similarly, when the Joint Sustainability Group of the Illinois DOT, ACEC-Illinois, and IRTBA developed the I-LAST tool, it made significant use of the NYSDOT's GreenLITES model and experience (FHWA, 2012).

This process continues as more states adopt sustainability measurement and rating systems. For example, the University Transportation Center for Alabama sponsored a project to develop sustainable transportation performance measures for the Alabama DOT and to develop a

methodology to implement a more sustainable transportation system. One of the tasks included reviewing sustainable transportation studies and initiatives in North America and Europe. This information will provide a framework for sustainable transportation performance measures and support development of a methodology for a sustainability enhancement tool, with identified data elements and data sources (Research in Progress database, 2012).

Just as the LEED building certification system fostered a widely accepted and cited system around which the public and private sectors have responded with enhanced green design and construction practices, so a broader national consensus on transportation sustainability measures and ratings might provide similar benefits.[9] Similarly, the various programs, such as U.S. EPA EnergyStar and WaterWise, have created a voluntary national certification program that provides market incentives for the private sector to standardize operations improvements around environmentally benign practices. Widely accepted measurement and rating systems would also provide for improved, and understanding of, public communication and outreach efforts as well as better focus on sustainability improvement needs and priorities for investment.

The FHWA's INVEST has the potential to enhance broad agency consensus around sustainability practices, measures, and standards, since it draws together lessons learned and measurement aspects of some of the better-known sustainability rating approaches already followed by a number of state and local agencies. INVEST is a web-based tool for self-evaluation of plans and projects that contains a collection of sustainability best practices. Table 38 shows these best practices, which are referred to as "criteria." Specific projects can be scored against these criteria to assess their sustainability. Scoring criteria may involve some subjective judgment, but where practical, empirically based ranking is used. Specifically, the intent of this tool is to do the following:

- Encourage more sustainable practices in roadway planning, design, and construction
- Provide a standard, quantitative means of roadway sustainability assessment
- Provide a standard means of assessing the sustainability of an agency's systems planning and operations programs
- Allow informed decisions and tradeoffs regarding roadway sustainability
- Enable owner organizations to recognize the benefits of sustainable road projects
- Communicate roadway sustainability to stakeholders

In concept, INVEST would operate in combination with some form of cost-effectiveness analysis to enable the comparison of options in planning, project development, and operations that could meet transportation goals. Based on estimated costs and risks of each option, each choice would be scored using appropriate INVEST criteria—providing explicit cost-effectiveness perspectives on each option from the sustainability point of view.

At this stage of development, INVEST offers rough ratings of sustainability-related "achievement levels" (including bronze, silver, gold, and platinum). Presently there is no provision for third-party INVEST-based certifications; rather scores are considered an unofficial recognition that a planning process, a project, or an operation has met a given threshold level of sustainability. (To achieve recognition as a sustainable highway project in the INVEST context, an evaluated project should earn at least 30 percent of the total points using the online self-evaluation tool.)

The research team notes that if an approach based on INVEST is adapted specifically for decisionmaking at an agency level, the criteria scoring could be further refined and weighted according to the particular conditions and priorities inherent in the regional, state, or local jurisdictions in which the tool is applied.

[9] In fact, NYDOT's GreenLITES program is explicitly modeled after the U.S. Green Building Council's LEED program and the University of Washington's Greenroads program. In addition, NYSDOT's certification program builds on other environmental initiatives that the department has already begun and is the next step in a long-term commitment to evaluating and refining practices to encourage sustainable choices in project planning, design, maintenance and operations (NYSDOT, n.d.).

Table 38. INVEST sustainability criteria—based on industry practices.

Criteria	Description
System Planning	
Integrated Planning: Economic Development and Land Use	Integrate statewide and metropolitan long-range transportation plans (LRTPs) with statewide, regional, and/or local land use plans and economic development forecasts and goals.
Integrated Planning: Natural Environment	Integrate ecological considerations into the transportation planning process, including the development of the LRTP and Transportation Improvement Program /State Transportation Improvement Program.
Integrated Planning: Social	The agency's LRTP is consistent with and supportive of the community's vision and goals.
Integrated Planning: Bonus	The agency has a continuing, cooperative, and comprehensive transportation planning process.
Access and Affordability	Enhance accessibility and affordability of the transportation system to all users and by multiple modes.
Safety Planning	The agency integrates quantitative measures of safety into the transportation planning process, across all modes and jurisdictions.
Multimodal Transportation and Public Health	Expand travel choices and modal options by enhancing the extent and connectivity of multimodal infrastructure. Support and enhance public health by investing in active transportation modes.
Freight and Goods Movement	Implement a transportation system plan that meets freight access and mobility needs while also supporting TBL sustainability principles.
Travel Demand Management	Reduce vehicle travel demand throughout the system.
Air Quality	Plan, implement, and monitor multimodal strategies to reduce emissions and establish a process to document emissions reductions.
Energy and Fuels	Reduce the energy and fossil fuel consumption from the transportation sector and document it in the transportation planning process.
Financial Sustainability	Evaluate and document that financial commitments made in transportation planning documents are reasonable and affordable.
Analysis Methods	Agencies adopt and incentivize best practices in land use, socioeconomic, and transportation systems analysis methods.
Transportation Systems Management and Operations	Optimize the efficiency of the existing transportation system.
Linking Asset Management and Planning	Leverage transportation asset management data and methods within the transportation planning process to make informed, cost-effective program decisions and better use existing transportation assets.
Infrastructure Resiliency	Anticipate, assess, and plan to respond to vulnerabilities and risks associated with current and future hazards (including those associated with climate change) to ensure multimodal transportation.
Linking Planning and NEPA	Integrate transportation system planning process information, analysis, and decisions with the project-level environmental review process, and reference it in NEPA documentation.
Project Development	
Economic Analyses	Using the principles of benefit–cost analysis or economic impact analysis, provide evidence that the user benefits, including environmental, economic, and social benefits, and justify the investment.
Life-Cycle Cost Analyses	Reduce life-cycle costs and resource consumption through the informed use of life-cycle cost analyses of key project features during the decisionmaking process for the project.
Context-Sensitive Project Development	Deliver projects that harmonize transportation requirements and community values through effective decisionmaking and thoughtful design.
Highway and Traffic Safety	Safeguard human health by incorporating science-based quantitative safety analysis processes within project development that will reduce serious injuries and fatalities within the project footprint.
Educational Outreach	Increase public, agency, and stakeholder awareness of the integration of the principles of sustainability into roadway planning, design, and construction.

Table 38. (Continued).

Criteria	Description
Tracking Environmental Commitments	Ensure that environmental commitments made by the project are completed and documented in accordance with all applicable laws, regulations, and issued permits.
Habitat Restoration	Avoid, minimize, and compensate the loss and alteration of natural (stream and terrestrial) habitat caused by project construction and/or restore, preserve, and protect natural habitat beyond the project.
Stormwater	Improve stormwater quality from the impacts of the project and control flow to minimize their erosive effects on receiving water bodies and related water resources.
Ecological Connectivity	Avoid, minimize, or enhance wildlife, amphibian, and aquatic species passage access and mobility, and reduce vehicle–wildlife collisions and related accidents.
Pedestrian Access	Improve the safety and convenience of pedestrian networks for people of all ages and abilities by providing or enhancing facilities within the project footprint.
Bicycle Access	Promote bicycling in communities by providing or enhancing safe and convenient bicycling facilities within the project footprint.
Transit and HOV Access	Promote use of public transit and carpools in communities by providing new transit and HOV facilities, or by upgrading existing facilities within the project footprint.
Freight Mobility	Enhance mobility of freight movements, decrease fuel consumption and emissions impacts, and reduce freight-related noise.
ITS for System Operations	Improve the efficiency of transportation systems without adding infrastructure capacity in order to reduce emissions and energy use, and improve economic and social needs.
Historical, Archaeological, and Cultural Preservation	Preserve, protect, or enhance cultural and historic assets and/or feature National Scenic Byways Program historic, archaeological, or cultural intrinsic qualities in a roadway.
Scenic, Natural, or Recreational Qualities	Preserve, protect, and/or enhance routes designated with significant scenic, natural, and/or recreational qualities in order to enhance the public enjoyment of facilities.
Energy Efficiency	Reduce energy consumption of lighting systems through the installation of efficient fixtures and the creation and use of renewable energy.
Site Vegetation	Promote sustainable site vegetation within the project footprint that does not require long-term irrigation, consistent mowing, or invasive/noxious weed species removal.
Reduce and Reuse Materials	Reduce life-cycle impacts from extraction and production of virgin materials by recycling materials.
Recycle Materials	Reduce life-cycle impacts from extraction, production, and transportation of virgin materials by recycling materials.
Earthwork Balance	Reduce the need for transport of earthen materials by balancing cut and fill quantities.
Long-Life Pavement Design	Minimize life-cycle costs by designing long-lasting pavement structures.
Reduced Energy and Emissions in Pavement Materials	Reduce energy use in the production of pavement materials.
Contractor Warranty	Improve quality and minimize life-cycle costs by promoting the use of extended contractor warranties for pavement.
Construction Environmental Training	Provide construction personnel with the knowledge to identify environmental issues and best practice methods to minimize impacts to the human and natural environment.
Construction Equipment Emission Reduction	Reduce air emissions from nonroad construction equipment.
Construction Noise Mitigation	Reduce or eliminate annoyance or disturbance to surrounding neighborhoods and environments from road construction noise, and improve human health.
Construction Quality Control Plan	Improve quality by requiring the contractor to have a formal quality control plan.

(continued on next page)

Table 38. (Continued).

Criteria	Description
Construction Waste Management	Utilize a management plan for road construction waste materials to minimize the amount of construction-related waste destined for landfill.
Operation and Maintenance	
Internal Sustainability Plan	Focus on sustainability improvements within the agency's internal operations that affect all three principles of the TBL.
Electrical Energy Efficiency and Use	Reduce the consumption of fossil fuels during operation and maintenance of agency-owned and/or -operated facilities through improvements in efficiency and the use and/or generation of renewable energy.
Vehicle Fuel Efficiency and Use	Reduce fossil fuel use and emissions in vehicles used for operations and maintenance.
Recycle and Reuse	Create and pursue a formal recycling and reuse plan for agency-operated facilities and maintenance activities.
Safety Management	Maximize the safety of the existing roadway network through a systematic and comprehensive review of safety data and the allocation of resources in planning and programming to support safety.
Environmental Commitments Tracking System	Ensure that environmental commitments made during project development related to operations and maintenance are documented, tracked, and fulfilled.
Pavement Management System	Leverage a pavement management system to balance activities that extend the life and function of pavements with impacts to the human and natural environment.
Bridge Management System	Leverage a bridge management system to balance activities that extend the life and function of bridges with impacts to the human and natural environment.
Maintenance Management System	Leverage a maintenance management system to inventory, assess, analyze, plan, program, implement, and monitor maintenance activities to effectively and efficiently extend the life of the investment.
Highway Infrastructure Preservation and Maintenance	Make paved roadway surfaces, bridges, tunnels, roadsides, and their appurtenance facilities last longer and perform better by undertaking preservation and routine maintenance on them.
Traffic Control Infrastructure Maintenance	Increase safety and operational efficiency by maintaining roadway traffic controls.
Road Weather Management Program	Plan, implement, and monitor a road weather management (including snow and ice control) program to reduce environmental impacts with continued or better level of service.
Transportation Management and Operations	Maximize the utility of the existing roadway network through use of technology and management of operations.
Work Zone Traffic Control	Plan, implement, and monitor work zone traffic control methods that maximize safety of workers and system users with continued or better level of service.

8.1.2 Third-Party-Scoring versus Self-Scoring Approaches

When widely understood, third-party rating and scoring systems have important advantages, particularly when the ratings are used to communicate with entities and interests outside transportation agencies, and when they are accompanied by well-defined standards for assessment. Third-party rating—consistently applied—can help acceptable sustainability practices to gain wide acceptance with the private sector, and with partner agencies. If the third party is a credible and objective entity (such as an industry standard–setting body or association with wide industry representation), the resulting ratings can be authoritative and useful in policymaking, project selection and design, and communicating benefits to public- and private-sector "investors." A disadvantage is that third-party rating systems necessarily gravitate toward one-size-fits-all standards of measurement that can be difficult to adjust or apply to specific agencies' project

settings and performance requirements, so that third-party rating may lack utility or credibility with project delivery practitioners.

Self-scoring systems are useful for more detailed and tailored assessments under location-specific conditions, agency operating structures, and performance requirements. These may be better suited to data-driven results, since agency data systems are more likely to be adapted to the rating system.

Rating systems such as those incorporated with INVEST and GreenLITES are based on self-scoring. Other systems such as STARS and Envision are based on a third-party scoring framework. In the case of Envision, the system is intended to provide a uniform means of assessing sustainability benefits for infrastructure practitioners, owners, and regulators. Unlike INVEST or state-developed systems, Envision is administered by the Institute for Sustainable Infrastructure, formed by ASCE, ACEC, and APWA.

There are useful, but distinct roles for both approaches. As rating systems of both types continue to proliferate and to be tested and refined, approach distinctions may narrow, as best practices are better understood and exchanged.

Eventually, a smaller number of complementary planning and project delivery sustainability scoring systems will emerge as "best of breed," and more states will chose and adapt to those.

8.1.3 Challenges in Incorporation of Multiple Modes

The research has pointed out that existing sustainability rating systems focus on mode-specific planning and programming, as well as project delivery and operations functions of transportation agencies. The rating systems studied do not address strategic investment decisions involving choice of modal alternatives and investments in nonhighway projects. There is no reason why similar rating approaches could not be developed and adapted to most infrastructure programs including transit, for example. Although some systems (e.g., INVEST) include rating criteria on linkage of investments to a broader transportation plan and associated goals, that broader planning process is not of itself assessed in the rating framework. Thus the rating focus remains clearly on the highway mode. Most systems have been developed to rate specific projects or programs rather than an integrated multimodal transportation plan.

Sustainability rating systems today assess programs and projects on a rating scale against established standards for sustainability best practices—not against other projects. Today's rating systems ask, "Given this rating system, how sustainable is this highway project?" rather than, "Could the transportation network performance needed be provided more sustainably by services and projects involving modal alternatives other than highway only?" Under today's policy system and governance structures, federal transportation agencies, and most state agencies that play roles in delivery of transportation services and infrastructure development, have mode-specific missions, so sustainability rating systems incorporating multimodal sustainability tradeoffs will be difficult to apply broadly at those levels, until the policy system and governance structures evolve further toward TBL. Some local governments and regional transportation planning organizations may be in better positions today to assess multimodal investment alternatives and contributions of multiple modes to the local or regional TBL, because their missions are less mode specific, but they typically have less influence on directing the flow of major transportation infrastructure investments to specific modes.

8.1.4 Effective Treatment of Intergenerational Equity

As observed in the research, many sustainability rating systems today focus on the impact of specific projects on selected TBL considerations. But TBL sustainability intends the long-term

preservation of society's assets, wherein present actions should not significantly diminish the quality of life or welfare of future generations. In general, this is a difficult concept for rating systems to capture, because the concept may involve comparing proposed actions or investments with no-action alternatives and possibly other alternatives. Some rating systems do attempt to address elements of this concept. For example, INVEST includes a criterion—financial sustainability—that requires practitioners to determine if financial commitments made in transportation system plans are realistic and affordable. To an extent, the financial sustainability criterion, and some of the other criteria, incorporates generational equity considerations, but the assessment approach for it is not explicit.

The generational equity concept may be best dealt with by cost–benefit analysis (CBA), using the discount rate principle. This places implicit values on benefits as they accrue to future time periods. Because most rating systems require that a CBA be conducted, CBA could be extended to account for future benefits (and costs). Regardless, the explicit concept of intergenerational equity—and coherent approaches to assessing it—is missing in most currently used sustainability rating systems.

8.1.5 Rating Agency Maturity in Sustainability Practices and Functions

It is potentially useful for agencies to assess and rate their respective "functional TBL-support maturity" levels, given plausible standards for transportation agency functional requirements to meet, under a future TBL sustainability policy system. As discussed earlier in the context of defining the policy system for TBL, such future functional requirements standards are (at best) subjective and can only be based on logic available today. Nevertheless, high-level agency ratings can help agencies and the industry at large to address functional gaps periodically, as and if a TBL sustainability policy system gains momentum.

The maturity assessment could be self-administered by transportation agencies, and/or it could be administered as a periodic structured agency survey and rating computation. The latter approach could be performed without attribution to assess the overall functional norms for transportation agencies and to assess whether functional gaps are closing over time.

The research team has prototyped a functional maturity survey tool that could easily be constructed as a spreadsheet-based tool. It contains simple rating choices keyed to each of the high-level transportation functions that have been framed in this report. Screenshots of this rating and survey model are shown in Appendix F, along with a brief description of the process for executing the assessment and determining maturity ratings. The actual choice descriptions are realistic, but preliminary and intended only to illustrate the concept.

8.1.6 Needs for Further Development—Sustainability Rating

Sustainability rating for the full range of transportation functions—fully addressing the concept of TBL and generational equity—is very important to assess and prepare for a TBL policy system. Such an evolution may involve a major cultural change and paradigm shift in the way transportation is conceived, funded, managed, and delivered in the future. Agencies' scores on numerous sustainability rating systems have signaled significant progress beyond context-sensitive planning and project delivery toward a more proactive approach to sustainable transportation, but the focus remains primarily on planning and project delivery. The aperture for sustainability rating initiatives needs to be widened to better encompass the full range of transportation functions; a more holistic view of a sustainable transportation network; more concise performance factors

Table 39. Needs for further development—sustainability rating.

Development Needs	Description
Rating approaches expanded beyond planning and project delivery functions	Broader rating and measures to better address performance of all major high-level functions including developing sector consensus on transportation needs, long-range planning, outreach and communications, decisionmaking collaboration with partner agencies and private sector, etc.
Ratings for how effectively programs addresses the full range of the economic impact of transportation investments	Improved definitions to rate how agencies consider impact of investments on regional economic development and growth, rather than focusing primarily on traditional cost–benefit assessment, where project costs are typically compared and evaluated against monetized mobility and safety impact.
More explicit rating treatment for agency consideration of long-range social welfare impact	Most TBL rating systems include some elements related to social impact. However, there is little consensus as to what should be included, how it should be defined, and how it can and should be measured.
Ratings to reflect the quality of agencies' consideration of long-term generational equity in the LRTP processes	The TBL benefits and effects of transportation investments normally have significant lag time after the investments, as development, land use, and travel patterns change and stabilize. Generational equity is an even longer-term concept. Agencies could examine and rate this investment aspect based on an extended time horizon for LRTPs, projections of transportation scenarios, and explicit equity measures and indicators.

outside of traditional mobility, safety, cost/benefit, and environment; and more comprehensive consideration of long-term generational equity effects.

Needs for further development of rating systems include the four major areas listed in Table 39.

8.2 Return on Investment and Communicating Benefits of Sustainability

ROI is a well-established method for evaluating investment decisions by comparing the present amount to the present value of the flow of value resulting from the investment. ROI provides a simple exposition of the net benefits from the *present perspective.* Monetized ROI is the easiest to communicate and evaluate. ROI can deliver a clear, unambiguous measure of the overall net benefits of a program or strategy in terms of current values and perspectives. For this reason, ROI it is a widely used technique and a critical tool for decisionmakers to select alternatives and communicate the prospective benefits of investment decisions to public and private constituencies.

Near-term infrastructure or service investment needs can be estimated and—assuming that future flows of value to the "capital stores" of each of the three bottom lines can be monetized or estimated in qualitative terms—there are opportunities to tailor investment approaches (or designs) for best-expected return overall. This form of analysis is tried and true, and very well-worn when applied in a purely monetized case, as in evaluating a prospective commercial business investment. The "art" of ROI analysis lies in estimating and incorporating values for nonmonetary benefits (e.g., environmental or social benefits and impacts). This can be addressed in part by use of quantified performance measures, so that the performance benefits that accrue for given investment strategies can be considered.

A major hurdle is left for SROI models that would rely on a combination of monetized and performance-related TBL benefits: *the need to credibly link and forecast the relationship of specific*

transportation investments to performance outcomes. Models exist in transportation to reasonably predict project effects on operational performance outcomes like improved travel times, throughput capacities, accident rate improvements, etc. Models like TranSight (a product of Regional Economic Models, Inc.) provide insights on the relationships of transportation projects and the economy. But these measures and models are not holistic, nor have the computational relationships been sufficiently correlated or borne out by real data to serve reliably as part of an SROI analysis. The challenges are greater when modeling the cause–effect relationship of transportation investments and environmental or social welfare measures.

This key issue was raised in the interviews conducted for this project. Estimating transportation ROI in sustainability terms and communicating the benefits of sustainability to key stakeholders are major challenges. In general, stakeholders agreed that simple monetized indicators of the benefits of sustainability would be the easiest way to communicate the value of sustainability and a desirable approach to judge the relative sustainability-based value of different investments. Experience with application of ROI indicators for sustainability investments in the private sector suggests that high-level ratings could be most effective. For example, Bloomberg's Sustainability Report for 2010 indicated that there was a 100 percent ROI in sustainability value for the firms it analyzed (Bloomberg L.P., 2011; the most recent report available at time of writing).

The several challenges that are apparent when applying SROI to assess or consider the sustainability of a public-sector investment are discussed in the following sections.

8.2.1 Concentrated Costs, Widely Distributed Benefits

Earthshift and the American Institute of Chemical Engineers (AIChE) Institute for Sustainability have developed an SROI methodology that explicitly addresses this issue, although not from a transportation point of view (Laurin et al., 2005). As can be seen in Table 40, it divides costs into those borne by the company and those borne by society as a whole. Furthermore, it identifies potential intangible costs or difficult-to-measure costs (e.g., customer loyalty, employee morale) that might affect the firm's bottom line.

This methodology includes a highly sophisticated treatment of uncertainty when it comes to the costs and the probability that the firm will incur them. Under this methodology, the firm identifies a series of potential investments and develops a series of scenarios that express

Table 40. Earthshift and AIChE Institute for Sustainability SROI costs classification.

Cost Type	Description	Examples
Direct Costs	Operating costs	Capital investment, operating, labor, materials, and waste disposal costs
Indirect Costs	Overhead and regulatory costs	Reporting costs, regulatory costs, and overhead monitoring costs
Future and Contingent Liability Costs	Potential fines, penalties, and future liabilities	Clean-up, personal injury, and property damage lawsuits; industrial accident costs
Intangible Costs (company paid)	Difficult-to-measure but real costs borne by the company	Cost to maintain customer loyalty, worker morale, union relations, and company community relations
External costs (not currently paid by the company)	Costs borne by society	Effect of operations on housing costs, degradation of habitat, effect of pollution on human health

Note: Classifications developed for private-sector firms for nontransportation purposes.

the potential futures for the investment. The firm then estimates the different costs that will be associated with each scenario. A Bayesian probabilistic analysis can be conducted to assess the probability that each scenario will occur, and a Monte Carlo probabilistic analysis is conducted to estimate the probability that a cost will occur. The two probabilities are multiplied (as a joint probability) to estimate the likelihood of the cost occurring. This value is then multiplied by the estimated cost to develop an expected value and compared for each proposed optional investment (including the baseline) to estimate the cost risk (and ultimately the ROI) for each option.[10] This has some promise as part of an SROI analysis, but the mathematics may be too complex to pass the "simply communicated to stakeholders" test in the transportation community.

8.2.2 Valuation of Nonmarket Benefits

Many of the benefits that arise from a public-sector investment are often nonmarket benefits. "Nonmarket benefits" are benefits that cannot be traded on a market—that is, benefits that do not have a market price and cannot be converted convincingly into monetary terms. They include such things as natural resource impacts, air emissions, and aesthetic values. There is a highly developed body of literature on the valuation of nonmarket benefits, and numerous techniques exist to value them [For example, see Champ et al. (2003), Freeman et al. (2003), Habb and McConnell (2003), and Hanley and Barbier (2009)]. However, for many stakeholders, these techniques are highly controversial. Furthermore, although it is possible to place a monetary value on many resources, it does not necessarily mean that this value will be realized or accrue to the investing parties, or will do so in the near term. In the first issue discussed above, although the public-sector transportation agency may be able to identify and quantify benefits in monetary terms, it does not mean the public will necessarily sense the benefits to confirm support of the investment. Because natural resource valuations are a "moving target" and are difficult to communicate to nontechnical audiences and key stakeholders, credibility tends to be downplayed. As a result, investment assessments tend to focus on the cost of the investment rather than a full consideration of the long-term benefits.

8.2.3 Financial Capacity or Willingness to Pay

ROI typically does not consider financial ability to pay or willingness to pay, or future funding streams. A project may appear to have a positive ROI, but when all demands on the funding agency are considered, the agency will not be able to support the future operations and maintenance of the system. This is often the problem that local governments face when each project or public investment has been viewed in isolation from other projects without considering the full project life-cycle costs, or the synergistic effects on TBL of multiple government programs. Thus, a single investment may be sustainable from a complete economic, social, and environmental point of view but not be fiscally or financially sustainable when considered in isolation. As a result, the investment cannot truly be said to be sustainable, because ultimately, the investment will not receive the proper ongoing support to achieve its goals, so generational equity is not well served. A long view over the financial life cycle may show projects to be less desirable than other project alternatives. Clearly this misjudgment could be at the expense of other projects that need funding and could provide better long-term value.

[10] This approach could be applied following along the scenario analysis conducted for this research. Under this approach, the analyst would attach a probability to the broad scenario identified in the report. Each impact related to transportation (positive and negative) could then be identified and a general magnitude of estimates of the cost developed. The probability multiplied by the magnitude would reveal an expected value. The cost of an investment that could avoid or mitigate the event could then be estimated, and the probability that it would achieve its goals could then be estimated. By combining the two probabilities, it would be possible to estimate the net benefit in terms of avoided costs.

8.2.4 Estimating Intergenerational Cost, Benefits, and TBL Value

"TBL sustainability" addresses concern for long-term or intergenerational costs and benefits. In formal welfare economics, benefits are measured as consumption or, in more sophisticated analyses, as Hicksian income. "Hicksian income" refers to the benefit derived from an asset when no portion of the asset is consumed. Hicks was originally only concerned with an individual's income (Hicks, 1946). This definition of individual income can be reformulated for a company as equal to "the maximum amount that could be distributed to the equity shareholders in a period and leave intact the capital value of the company's prospective receipts as at the beginning of the period" (Solomons, 1961). This is a key definition. In environmental economics, Daly applied Hicks's concept to society as a whole. Specifically, Daly argued for the extension of Hicks's category of capital to include natural resources (because they can be thought of as part of society's assets; see Daly (1974). The implication is that any estimate of national or social income should consider the erosion of natural asset stocks (this corresponds to asset sales in Hicks's model). Furthermore, Daly's perspective suggests that we should include a wide concept of income—that is, if natural resources are regarded as "assets," then all the benefits arising from those assets (e.g., ecological services) should be considered "income," and the category of income should not be confused with the "output" only (as is normally done in national income accounting). For Daly, "output income" is simply the value that can be consumed and is not synonymous with income or welfare.

From the point of view of intergenerational accounting, the implication of Daly's concept of income is that losses to the natural capital stock at any "bottom line" should be accounted for and discounted over time. Thus, any income derived from the use of a natural resource must be considered in the context of future losses. In this analysis, the assumed social discount rate becomes critical. The social discount rate represents the value placed on future marginal social costs and benefits over current marginal social costs and benefits. For example, what is the value placed on mining metal today and using the iron for industry versus the loss of the ore to future generations? Essentially, the discount rate puts a price on future generations' welfare versus the current generation's consumption (Portney and Weyant, 1999).

The problem with this ROI or cost–benefit approach is that the value of the social discount rate is arbitrary and highly controversial. For example, the Stern Review on global climate change (Stern, 2007) uses a social discount rate of effectively 0 percent, arguing that to select any other rate is unethical and immoral in that it takes choices away from individuals who cannot be party to the choice (i.e., individuals who are not yet born). This has the effect of making future impacts the same as current impacts. Many economists argue that this is unrealistic. They point out that future costs will be less than current costs, because of the following reasons:

- Future consumption takes place in the future and, based on behavioral economics experiments, human beings generally prefer consumption in the present to the future (known as *inherent discounting*).
- Consumption levels, human welfare, economic growth, and global wealth will be higher in the future, so the marginal utility of additional consumption will be lower (i.e., in the future, the relative cost of environmental protection will be lower than today, because we will all be richer).
- Improved technology of the future will make it easier to address future environmental concerns or may eliminate them altogether.

Even when a more "realistic" value is placed on the social discount rate, the value is still arbitrary. Table 41 shows the range of methods used to estimate discount rates by some federal agencies. The Office of Management and Budget (OMB) is perhaps the most influential. However, the discount rate that OMB uses is not a social discount rate: It is based on budget, inflation, and economic projections concerning interest rates rather than a consensus view of the value of future

Table 41. Sample methods for estimating discount rates.

			Parameters Employed in Estimating the Discount Rate		
Reference	Approach	Data	Real Interest Rate	General Inflation Rate	Nominal Interest Rate
OMB Circular A-94	Deterministic	Long-term treasury real interest rate	●		
FHWASA-98-079	Probabilistic, Latin hypercube	Recorded historic rates	●		
FHWASA-98-079	Deterministic	Average historic rates		●	●
FHWASA-98-079	Probabilistic, Latin hypercube	Recorded historic rates		●	●
FHWASA-98-079	Probabilistic, Monte Carlo	Recorded historic rates	●		
FHWASA-98-079	Assumption	Assumption	●		

investments. As a result, this rate changes to reflect current economic circumstances and beliefs about the future. Over the last two decades, the 30-year OMB discount rate has varied from 8.1 percent to 2 percent. Simply changing this rate can make certain investments seem suddenly economically viable or nonviable and does not reveal a real, consistent estimate of the true value of future costs and benefits compared to the present.

Because of these issues, a number of analysts have proposed the use of alternative, nonmonetary methods of estimating the sustainability impacts of transportation investments. At one extreme are some scientists and ecologists who would eliminate economic valuation altogether and replace environmental calculus with alternative measures, such as the impact of investment decisions on the physical accounting of the stocks of natural resources [see, for example, Bojö et al. (1990), Theys (1989), and Alfsen et al. (1987)] or the maximum sustained utilization rate for elements of the environment or critical loads [see, for example, Hall (1993)]. Advocates of these approaches argue that they remove the need for monetary valuations, because they directly address the issue of viability of the natural environment and human interactions with the environment (i.e., the "society" and "economic" elements of the TBL). In response, most economists would argue that these elements can be considered within the conventional framework of economics if properly valued and that mechanisms based on purely noneconomic measures are ultimately arbitrary (in that they impose one group's valuation of an asset on another group when neither party can be said to own the asset) and inefficient [for example, see Dubourg and Pearce (1996)].

A less extreme position argues for the use of sustainability scoring methods or indices to assess the impact of proposed transportation investments. In this model, an investment would be scored using a sustainability evaluation system and either (1) this would be used as general input to the decision along with conventional ROI or CBA or (2) only alternative investments that scored above a certain sustainability score would be considered in the CBA, ROI, or financial analysis.

This issue raises the basic problem that ROI analyses face when dealing with sustainability. Ecologists and economists generally have two different paradigms when it comes to the definition of "value." Ecologists define "value" as the contribution a process makes to the ecosystem as a whole, or the intrinsic worth of a process or element of the ecosystem (Cordell et al., 2005).

In contrast, economists see "value" as instrumental—that is, an object or process only has value in terms of the degree to which it contributes to some end. Thus, a wetlands that is affected by

highway development will have an intrinsic or process value to an ecologist, while it might have an instrumental value to an economist equivalent to the degree that it helps some contribution to human welfare (e.g., water quality improvement, fish and wildlife availability, flood control). This fundamental difference is often encountered when there is an attempt to value environmental (and by extension, social) goods and services.

Furthermore, ecologists and economists have a fundamentally different view of the nature of investment, capital, and income (the basis of ROI calculations). Ecological economics (from which the concept of sustainability emerges) attempts to ground economics within the broader context of the laws of thermodynamics and ecological systems analysis. Ecological economics views the human economy as being part of a large environmental system that can be understood as a series of energy and matter transfers between different participants. This system is a complex web of interconnections in which each element contributes something to other nodes within the system. Removing too much energy or material from one element will affect the system as a whole and affect its overall functioning. Thus, each element is not tradable or substitutable. Furthermore, there are basic minimums required for key system sustaining operations. For example, plants and trees allow for carbon dioxide to be translated into oxygen via photosynthesis. If all the trees and plants were to die, there would no mechanism to convert carbon dioxide into oxygen.

Thus, ecological economics challenges the basis assumption of neoclassical economics that natural resources are simply an input into production. Critically, the potential for the substitution between manmade capital (e.g., physical infrastructure, financial instruments) and natural capital is critically different under the two paradigms. Under the neoclassical economic perspective, natural capital can be traded for human capital to reach an optimum benefit for human beings. Thus, manmade capital can, in principle, replace all types of natural capital. As noted previously, this is known as "weak sustainability" (Solow, 1974, 1986, 1993; Hartwick, 1977, 1978).

Under ecological perspectives (strong sustainability), all forms of capital must be maintained intact independent of one another. The implicit assumption is that different forms of capital are mainly complementary—that is, all forms are generally necessary for any form to be of value. Produced capital used in harvesting and processing timber, for example, is of no value in the absence of stocks of timber to harvest. Only by maintaining both natural and produced capital stocks intact can nondeclining income or value be assured (United Nations, 2005).

This is a fundamental difference in how people conceptualize the allocation of scarce resources and value different goods. Critically, it is difficult to fit this ecological economics perspective into an ROI paradigm, because it would require valuing the elements of the overall ecosystem in relation to the other elements of the TBL equation.

As a result, most SROI approaches are based on the general theoretical framework of welfare economics (i.e., weak sustainability), with the discount rate being used to estimate the value of future capital. Three fundamental assumptions underlie this paradigm (see Freeman III, 2003a, 2003b):

- Improving human welfare and well-being is the fundamental goal of all economic activity.
- Individuals are best able to determine their own good and how well off they are given any set of circumstances.
- The welfare of society as a whole is measured by aggregating all individuals' welfare across society.

"Welfare" then is fundamentally defined as the aggregation of individuals' preferences and their willingness to pay for overall gains (essentially, a benefits transfer) or to accept compensation for losses [see Samuelson (1983); Chipman and Moore (1978)]. Sustainability fits into this perspective via an inclusion of the analysis of the environmental and social impacts of individual consumption decisions and a valuation of those decisions [see Daly and Cobb (1989)]. This

requires a careful valuation of these impacts, which, as noted previously, can be controversial. However, systems such as HDR's SROI methodology does attempt to do this. And, it would be theoretically possible to convert many of the items in sustainability rating tools into monetized elements and estimate the total ROI.

8.2.5 Difficulty in Creating "One-Size-Fits-All" ROI Models

SROI models are not easily standardized or used as a simple spreadsheet model or tool. Rather, the approaches or methodologies require considerable customization and are expensive to use. For example, as discussed earlier, HDR's SROI service offering is not (strictly speaking) a tool. Although at the core of the approach is an Excel model, it is actually a consulting package. A transportation agency must hire HDR, which then comes in and identifies the issues affecting sustainability for a specific investment, converts and monetizes these variables where possible, collects data, and analyzes it to create customized estimates of the sustainability costs and benefits.

Similarly, PricewaterhouseCooper's sustainability offerings are "processes" rather than "tools" that are proprietary to the firm, designed largely for the private sector, focus mainly on economics and environment, and require substantial customization and commitment of time and resources from clients to implement.

European tools [such as the ESCOT and the Assessment of Transportation Strategies (ASTRA)] are similar. ESCOT, developed to help support a path toward a sustainable transport system for Germany, is a tool for assessing the economic and environmental impacts of different transportation options. ESCOT is a highly complex model that uses a system dynamics methodology to create an integrated model of different transportation scenarios. At its core is a Keynesian input/output macroeconomic model [similar to U.S. systems like Impact Model for Planning (IMPLAN) or the Regional Economic Models, Inc. (REMI) model] that forms the backbone of the economic assessment and enables users to explore complex policy choices. ESCOT contains the following modules:

- A macroeconomic model supplies information on the aggregate economic level (e.g., national income, GDP, employment)
- A regional economic model is disaggregated into 12 different economic sectors, and nine functional types of regions are defined (e.g., rural regions, highly agglomerated areas)
- A transport model estimates impacts for different transport modes (road, rail, water, air) and different types of infrastructure links (e.g., high-speed links between agglomerations)
- An environmental model calculates data on emissions of transport activities and estimates their first-round effects
- A policy model drives the scenarios that influence the other model system

Most policy implementations intervene in the transport model such that this model usually is the steering area for simulating the impact mechanisms. Needless to say, the model is highly complex and requires massive amounts of data to run. Furthermore, each variable set (e.g., policy variables) has to be structured for the scenario to be run, and the relationships of those policies to specific outputs has to be specified by the user [for details, see Schade and Schade (2002)].

The ASTRA project was initiated in 1997 by a European consortium—consisting of Institut für Wirtschaftspolitik und Wirtschaftsforschung, Universität Karlsruhe, Germany; Trasporti e Territorio, Italy; Marcial Echenique & Partners, United Kingdom; and Centre for Economics and Business Research, United Kingdom—and co-funded by the European Union and Federtrasporto, Italy. The aim of ASTRA is to develop a tool for analyzing the impacts of the European Common Transport Policy, including secondary and long-term effects. ASTRA uses a system dynamics

platform (ASP) to link macroeconomic changes, regional economics and land use, transport, and the environment. It is composed of four submodules:

- The macroeconomics submodule (MAC)
- The regional economics and land use submodule (REM)
- The transport submodule (TRA)
- The environment submodule (ENV). [For more information, see Schade et al. (1999).]

For purposes of this report, several points can be made about ESCOT and ASTRA:

- **The models are not true sustainability models:** ESCOT and ASTRA focus on the interaction among economic, transportation, and environmental impacts. They do not address social impacts or broad environmental impact. They are more analogous to input/output models such as REMI TranSight [which links transportation, environment (in the form of air emissions), and economic development].
- **The models require substantial user involvement, analysis, and data collection:** Input/output models require substantial user involvement, data collection, and customization to run. The sophistication of models such as ASTRA, ESCOT, and REMI are achieved by the inclusion of a large number of variables that can be adjusted and modified (e.g., the REMI model has more than 5,000 variables that can be manipulated). Users and analysts need to take an active part in setting and adjusting these variables. This frequently requires extensive data collection and expertise to understand which variables should be modified and the magnitude of the change. This process can take months and require substantial stakeholder input and consensus building.
- **The models require underlying system data:** All macroeconomic models require the development of an underlying data set and set of algorithms that specify the linkage between different industry sectors and locations. This requires analysis of economic data and the development of complex input/output tables. These tables are extremely difficult to develop and are frequently purchased from vendors that develop them. For example, REMI data tables can be bought under a limited license for a specific region in the United States for approximately $15,000. ESCOT's underlying data is limited to certain European countries. If a version were to be developed for the United States, all the data would have be developed.
- **The models are not ROI models:** ESCOT and similar models are, strictly speaking, not ROI models. ROI models estimate a rate of return on an initial investment. Cost–benefit models discount the future benefits stream to present value and divide by the present value of costs, while economic and environmental impact models examine the economic and environmental impacts of different investments and policies. These seem to be unimportant distinctions, but models like ESCOT are designed to show the impacts of different system-wide scenarios rather than the return on an investment to a specific community, state, or region. As such, although they are useful for broad policy analysis, they are not useful for detailed analysis of specific projects.

It should be emphasized that analyses such as those that can be conducted with ESCOT and ASTRA are regularly conducted in the United States for environmental impact statements and major economic and transportation projects. CBAs routinely conducted for most major public transportation projects consider the transportation, environmental, and economic impacts of investments. These analyses frequently use macroeconomic models [e.g., Global Trade Analysis Project (GTAP), Regional Input/Output Modeling System, IMPLAN, REMI] combined with transportation and environmental models (e.g., EPA's Motor Vehicle Emission Simulator). Similarly, models such as RTI Applied Dynamic Analysis of the Global Economy integrate economic and environmental impacts of carbon-reduction policies using GTAP and REMI as a basis. In fact, there are literally hundreds of models that could be used to estimate different transportation, environment, and economic interactions. What is lacking is an easy way to combine these models to estimate the impact of different investments, policies, and system-wide changes. Furthermore, for these models to be truly sustainable, it would be necessary for (1) the consideration of broader economic impacts than air emissions (the only environmental

impacts normally considered) and (2) the development of social factors to be incorporated into the model.

While it is true that many of the existing SROI models do not address all the dimensions of sustainability, it should be emphasized that this does not mean that they cannot play a significant role in the public debate over proposed investments. For example, Parsons Brinckerhoff's PRISM attempts to estimate full TBL impacts. However, Parsons Brinckerhoff does not see a TBL impact produced by PRISM as necessarily being a definitive statement of the full TBL impacts. Rather it is a way to begin the public discussion on TBL impacts. Thus, according to Parsons Brinckerhoff, PRISM's TBL module:

> "is intended to build upon . . . environmental analyses, bringing economic and social factors onto a level playing field and applying transparent and defensible ways to monetize the full range of relevant factors. By bringing analytical rigor to the principles of sustainability, and by not focusing on finding a single "correct" answer, the . . . tool can help focus the dialogue as a learning experience to provide an enriched understanding of what is really at stake in the consideration of projects, plans, policies, and programs" (McVoy and Gunasekera, 2011).

These models could then support an approach that—if used along with active public involvement—could advance understanding and decisionmaking on TBL impacts and benefits.

In addition, these models would need to be simplified to develop ROI estimates that could be used in decisionmaking. Techniques exist that can be used for this. For example, it is possible to take multiple runs of the REMI model to establish a range of outputs for different highway investments. These outputs are then converted into a distribution and used in a simple spreadsheet model. By combining these with transportation model runs and environmental impact models, it is possible to develop a simple spreadsheet model that provides substantial sophistication.

8.2.6 Need for Further Development—ROI Models

Based on this analysis, it can be concluded that there are no adequate SROI tools at present. Table 42 identifies key requirements for further research and analysis in this area.

8.3 Life-Cycle Cost Analysis, Life-Cycle Assessment, and Cost–Benefit Analysis

Several techniques exist that attempt to assess the full life-cycle impacts of investment. For example, LCCA attempts to develop a complete cost profile of any investment. LCA attempts to estimate environmental impacts associated with all the stages of an investment's life from cradle to grave (i.e., from raw material extraction through materials processing, construction, operation, repair and maintenance, and disposal or recycling). CBA attempts to estimate the net benefits (i.e., benefits minus costs adjusted for time) of an investment. All face similar issues and challenges. Specifically, all face major challenges dealing with estimating the full range of costs and benefits and addressing issues related to intertemporal and interpersonal utility functions (i.e., what is the value of the future to different people).

8.3.1 Life-Cycle Cost Analysis

In some ways, LCCA faces the biggest challenges. LCCA has a long history. The concept of LCCA in road construction was first discussed in AASHTO's "Red Book" in the 1960s, but it did not appear as a requirement in federal legislation until 1991 with ISTEA. ISTEA required consideration of "the use of life-cycle costs in the design and engineering of bridges, tunnels, or pavement." The National Highway System Designation Act of 1995 further imposed a new requirement making LCCA compulsory for National Highway System projects costing more

Table 42. Development needs—ROI models.

Development Need	Description
Consensus on the range of impacts to be included in the ROI estimate	As with sustainability rating systems, there needs to be a consensus on the items that should be included in SROI estimates and the scope of these elements (e.g., society-wide? region-wide?). Additional research is needed to identify potential elements and develop a consensus around these elements.
Accepted definitions of these impacts and methods for estimating these impacts	Following on from the above issue, there needs to be additional research to define what is included in each benefit and establish a methodology for estimating and monetizing costs and benefits. Critically, there needs to be an accepted approach to estimating nonmarket costs and benefits.
Consensus on meaningful discount rate or methodology dealing with intergenerational costs and benefits that specifically express the value of future costs and benefits over a long term	A critical element of sustainability is the concern for long-term or intergenerational benefits. Currently, cost–benefit and ROI analyses address this issue via the discount rate. However, the discount rate as typically used in federal, state, and local governments in the United States is not used for long-time horizons (e.g., greater than 30 years) and does not really represent a time preference for money (as it is based on anticipated interest rates and returns). Either a new method of estimating long-term costs and benefits (perhaps using ecological models) or a more meaningful discount rate system needs to be developed. Additional research is needed to resolve this issue.
Clear understanding of methods of distributing costs and how investment decisions will impact different groups	Equity is a key issue for ROI benefits. In a representative democracy like the United States, no government program can be indifferent to who, where, or when costs and benefits are experienced. There needs to be a consensus as to how equity issues should be addressed from a geographic, social, and temporal basis. Additional research is needed to resolve these issues and help identify the data needed and methodology to be used.
Integration of long-term sustainable funding perspectives into the methodology	Sustainable systems will remain sustainable if the initial O&M funding assumptions that are made are supported into the long term. ROI estimates need to include some assessment of the probability of future support and the risk involved in not delivering on these commitments. As such, research needs to be undertaken to determine how to integrate these elements into SROI estimates.
Consensus on valuation of social impacts	The social elements of the TBL are notoriously difficult to define and measure. Most ROI estimates tend to translate the social elements into protection for cultural or historically important sites or equity issues. However, the initial definitions of "sustainability" implied that more is meant—that is, the sustainability must create a society that will support and enable people to live meaningful lives where the human costs of achieving the other elements of the TBL are not too high. It might be that future sustainability measures and ROI estimates will abandon this idea, but if we wish to capture the full depth of TBL, additional research will have to be developed to determine how to define, measure, and monetize this element of the TBL.
Consensus on principles for trading and balancing between the three bottom lines	Current ROI models are based around an idea of weak sustainability that allows substitution of human for natural capital and economic for social capital. The TBL implies that there should be some limit to this trading (i.e., that there are some limits in each element beyond which they cannot go). Research needs to be conducted to explore this issue and develop methodologies and tools that permit trading and limit exchange between different elements of the TBL.
Development of an easy-to-use tool to estimate and communicate sustainability choices	Current approaches to SROI are costly and require a substantial level of effort. There needs to be an effort to develop a simple tool (perhaps in spreadsheet form) that can be widely used to develop consistent and meaningful estimates of sustainability. This would permit comparison between projects and allow for more sustainability-based resource allocation.

than $25 million. The requirement was annulled under the Transportation Equity Act for the 21st Century (TEA-21) in 1998, but the FHWA and AASHTO remain active in assisting the states in developing their own LCCA procedures. The FHWA is required by TEA-21 to fund research that "expands the knowledge of implementing LCCA" (23 USC 502), and life-cycle costs must still be considered as part of the FHWA's value engineering process for National Highway System projects costing more than $25 million [see Chan et al. (2008)].

This has resulted in widespread use of LCCA. For example, a survey of 33 state DOTs in 2006 found that 91 percent of respondents (30 states) used LCCA. Most used well-established tools and techniques. For example, eight states use the RealCost software, which is a spreadsheet model released in 2002 based on the FHWA LCCA Bulletin of 1998, and three states use the Darwin software products (developed by AASHTO). Darwin incorporates an LCCA module and provides a powerful pavement design program and a computerized version of the 1993 *AASHTO Guide for Design of Pavement Structures* [see South Carolina DOT (2008)]. Given the widespread adoption of LCCA and the widespread availability of models and tools, the appropriate model for LCCA has not been addressed.

However, despite the popularity of LCCA, there are several issues when it comes to the TBL. For example, as discussed previously, future costs are calculated using a discount rate. As noted, the discount rate expresses the value of future costs versus current costs. This is a critical parameter for sustainability analyses as it is the main tool by which long-term intergenerational costs are estimated. As discussed earlier, in the United States the discount rate is not used in this way. Rather it reflects a set of assumptions concerning the interest rate and future expectations concerning economic growth and the inflation rate. Furthermore, LCCA does not deal with the risk involved in making irreversible decisions and the costs of denying these foregone opportunities to future generations. Therefore, in the realm of estimation of future costs and the impact of these decisions, LCCA is deficient.

Similarly, as with other financial tools, LCCA has problems translating environmental and social costs into monetary terms. A full sustainability life-cycle cost should address all the costs associated with an investment. This means that environmental and social costs should be considered and weighted in importance relative to other costs [for more discussion of this issue, see Gluch and Baumann (2004)]. As has been discussed previously, despite substantial analyses in this area, there is still considerable dispute as to how to value these impacts and weight them relative to easier-to-monetize effects associated with direct economic impacts. LCCA needs to develop a consensus method to identify which impacts to include and how to value and weight them relative to other costs.

In addition, LCCA faces the challenges that ROI estimators have faced in including social impacts. As previously discussed, social impacts are the most difficult to define and monetize. Including them in an LCCA calculation and measuring and weighting them is a major challenge. Even the inclusion of equity measures (e.g., Who pays over the life cycle?) would mark a major departure from current practices.

There have been some suggestions as to how LCCA can be improved to better capture sustainability issues. For example, sustainability advocates have proposed that LCCA should be modified to consider a "whole system design" approach [see Bloomfield et al. (2006)]. The whole system design approach is a process for actively considering the interconnections between subsystems and systems, and solutions are sought that address multiple problems via one and the same solution (Stansinoupolos et al., 2008). Essentially, the approach requires that engineers cease analyzing their design in isolation to the environment and begin to explore the hidden assumptions, costs, and impacts that are evident when the interconnections between different elements and the overall environment are considered. Thus, in a traditional engineering approach, each element of a system is optimized for cost, energy use, and performance in isolation, rather than

optimizing an entire system as a whole and considering all resulting costs and benefits that could make the entire system less efficient and optimal (and more expensive). For example, improving a road or bridge to take more trucks typically focuses on an analysis of expected traffic and truck weight and design and materials analyses. A whole system engineering approach would explore the assumptions that lead to the decision to move freight from rail to road and consider the full impact of road freight. This would include assessing all the costs (environment, safety, etc.) and estimating these costs. When all these costs are considered, a previously efficient, cost-effective approach may come to be seen as costly and ineffective.

8.3.2 Life-Cycle Assessment

LCA is in many ways a response to LCCA issues and embodies many of the concepts of whole system design. By focusing on the life-cycle environmental impacts of an investment, LCA generates a complete inventory of relevant energy and material inputs and environmental releases and the potential impacts associated with identified inputs and releases. As defined by ISO 14040 and 14004, LCA consists of three stages:

- Define goal and scope
- Develop life-cycle inventory
- Conduct life-cycle assessment

The initial stage is vital to the overall analysis. The danger of LCA is that it can be extended backward into the supply chain to such a point where almost the whole economy can be considered as contributing some cost elements to a specific investment. As such, it is vital that the analysis begin by bounding the analysis and stating clearly which impacts will be considered. Thus the initial stage:

- Defines the functional unit to be studied and identifies the service to be delivered by the investment;
- Establishes the system boundaries (i.e., which impacts will be considered);
- Defines assumptions and limitations;
- Describes the allocation methods that will be used to partition the environmental load of a process when a number of products, investments, or functions share the same process (e.g., if cement is used for construction, the analysis needs a method for partitioning the fixed capital that went into producing the cement as that asset has been used to produce cement for multiple purposes outside the functional unit under analysis); and
- Describes the impact categories chosen (i.e., which environment media will be analyzed and how far into the ecosystem impacts will be considered).

Once the scope has been defined a life-cycle inventory analysis is conducted. This involves creating an inventory of energy and material flows (e.g., flows of water, energy, and raw materials, and releases to air, land, and water) from and to the natural environment for the investment using a flow model. A flow model illustrates activities that are going to be assessed in the relevant supply chain and shows the system boundaries.

A flow model can be extremely complex. It can show hundreds of different flows depending on how the system boundary is defined. Often extensive engineering and supply chain analyses are needed for each flow.

In the life-cycle impact assessment phase, impact categories are identified, impact indicators are developed, and models are developed to characterize the magnitude of the impact. Impacts are then sorted and assigned to specific categories and a "common equivalence unit" (i.e., a scale or common measurement indicator) is developed to compare and combine different impacts. In some cases, these impact scores are then normalized, grouped, and weighted.

While LCA is an appealing technique, it has a number of problems in application to TBL assessment:

- First, it is extremely expensive to conduct. Identifying and describing the impacts of different supply changes can be extremely costly. In many cases, the environmental impacts of many processes or elements of the supply chain will not have been identified and will require new research. This can somewhat be mitigated by the development of standard impact measures. For example, it would be possible to estimate the total environmental impacts of moving one ton of cement from a typical site. An analyst could then use this factor and adjust for the distance the cement traveled to reach the construction site and obtain a total environmental impact.
- Second, LCA only looks at costs. LCA is intended to be used as a tool to compare the costs of investments or analyze a specific supply chain. There is no analysis of the benefits that an investment might bring in environmental, economic, or social terms. Thus, while an investment may have a high environmental impact (e.g., the cost to build and operate a light rail system), it may have considerable benefits in economic terms (e.g., reduction in congestion affecting the average time spent in commuting or the time taken to deliver freight in an area, reduction in social cost associated with reductions of automobile accidents), environmental terms (e.g., reductions in emissions from mode shift, reducing congestion and long-term land use changes), or social terms (e.g., new communities emerging around light rail stations). These benefits can be included in the analysis, but if this is done then the technique comes to be more like a CBA rather than an LCA and encounters other problems (discussed below).
- Third, as with other sustainability assessments, LCA suffers from the difficulty of measuring impacts in a "common equivalence unit." For LCA to work, all costs must be converted into the same unit of measure. This unit can be monetary or some other unit (e.g., tons of GHG, kilowatts of energy). As with other techniques, it is difficult to develop a consensus of which units should be used and how elements should be valued and normalized in that unit of measure. If monetary values are used, there are the issues related to the valuation of nonmarket goods. Similarly, the development of new "environmental impact measures" has other problems, such as explaining what the category means, developing equivalent units for different impacts, establishing trading and transitivity rules between different impacts, and measuring and converting impacts to those units.
- Fourth, as with other techniques discussed, LCA has difficulty in dealing with long-term or intergenerational costs. In LCA's case, this problem is made even worse if LCA is used in retrospective analysis when past costs are included (i.e., exploring the antecedent costs in the supply chain). Most economic costs treat used resource as a sunk cost and therefore do not include them in the analysis. The rationale is that, as nothing can be done to affect these costs, they are irrelevant. However, any LCA analysis has elements of a retrospective analysis if it includes any consideration of fixed assets bought before the analysis began. If they are to be included in the analysis, LCA not only requires a discount rate for the future but also a discount rate for the past (i.e., How much should resources used in the past be valued?). This is an extremely difficult problem. Furthermore, if nonmonetary values are used, it becomes extremely difficult to develop a system to value future cost and benefits vis-à-vis current benefits. For example, is a ton of GHG released today of more inherent value than one released tomorrow? These are difficult questions that have not yet been resolved.
- Fifth, LCA is explicitly an environmental analysis. It does not address the other elements of the TBL (society and economic costs and benefits) and therefore may miss important impacts of any investment.
- Sixth, LCA does not address equity issues and interpersonal valuation. While LCA may create a long list of impacts, it does not consider who will experience those costs and how those individuals value those costs. For example, at the most superficial, two investments may have the same total environmental cost but whereas one spreads the cost through the community,

the other requires that a small, disadvantaged group experiences all the cost. This would not be considered in an LCA analysis.

A more subtle but equally important issue is related to the conjunction of equity and interpersonal valuation. LCA attempts to impose a single valuation of all assets and operations. This valuation is developed from a particular approach and methodology. This methodology is selected by individuals what have normative values and bias. While it may be claimed that this view is based in a scientific understanding (e.g., an energy-balance analytical paradigm), this is still a subjective choice. Alternative and equally valid ways of assigning and computing value exist. Often individuals that are affected by an investment somewhere in the supply chain have different valuations of a process or asset. The impacts on those individuals (and how they value them) can be very difficult to compare when complex scientific or newly created units are developed.

For example, an LCA conducted on a proposed street car system might consider the impact of generating the electricity to run a street car. If electricity is assumed to be generated by a coal-fired power plant, LCA could (if it were in the system definition) trace back the supply chain and identify the impact in GHG terms of coal, for example, increased runoff of poor-quality water and erosion from spoil piles, recharge of poor-quality water to shallow groundwater aquifers, poor-quality water flow to nearby streams, impacts on fish and wildlife, mercury emission and impacts on land (e.g., from mountain top removal). However, many individuals involved in the coal industry would find these costs acceptable given the benefits provided to workers in the industry and surrounding communities. For large social investments, the failure to consider these alternative valuations frequently leads to opposition and discord. It is important to stress that such a debate can occur when neither party is wrong; both can accept the description of the impacts of a decision but differ on the values they assign to resources involved. Furthermore, the use of a new, often difficult to understand impact measure (e.g., kilowatts of energy, tons of GHG) makes it difficult for groups involved in disputes to understand what is truly at stake and what they would be willing to trade to achieve a compromise.

In welfare economics, this issue can be addressed via the use of the "compensation principle." This is a decision rule used to select between pairs of alternatively feasible outcomes. According to the compensation principle (under Kaldor-Hicks efficiency), if the prospective gainers from one choice could (not necessarily would) compensate prospective losers, and leave no one worse off, then that option would be selected. Alternative formulations exist. For example, under the Pareto principle, any change that produces gain must produce at least one entity that loses. This underlies the Pareto 80/20 rule for decisionmaking. LCA does not address these issues. More sophisticated forms of analyses such as CBA can address these concerns.

8.3.3 Cost–Benefit Analysis

CBA is perhaps the most sophisticated approach to assessing the impacts of sustainability. Of course, as can be seen from the previous discussion and the discussion of ROI and sustainability, sustainability CBA creates numerous challenges related to intertemporal and interpersonal valuation and valuation of complex ecosystems and raises major ethical questions concerning the value of the natural world. Furthermore, CBA has difficulty in addressing social values.

While there are numerous equity and compensatory tools in CBA, it is more difficult to place a value on nonmarket social values. Various approaches (e.g., stated and revealed preference) can be used to estimate these values, but they are very controversial (especially when equity impacts are involved). For example, CBA has considerable problems in addressing the issue of "sense of place." Sense of place is defined as the set of place-related meanings and place attachments held by an individual, group, or community. It represents the bond that human beings feel to a place that is formed by a collection of experiences, meanings, myths, histories, or attributes [see Semken

(2012)]. Critically, the conditions that create a sense of place are indivisible. For example, if a town square creates a sense of place for a community, a half a town square with a parking lot on the other half may not. Transportation projects often have major impacts on sense of place. New roads may bring new residents to an area (changing the place) or create new economic conditions (e.g., roads allowing trucks to travel through previously isolated places). Often people are prepared to trade this sense of place for increased income or opportunities. However, sustainability offers the prospect of being able to balance these social dimensions with other elements of TBL.

While estimating the value of these other elements may be controversial, there at least exist methodologies to estimate economic and environmental impacts; almost no tools or methodologies exist to value social impacts or even enumerate their full impacts. This is particularly important because the threat of the loss of these social or community values is often what has led to community revolts against transportation projects. For example, the highway revolts of the 1960s and 1970s occurred directly as a result of the perception that new highways were destroying existing communities. Similarly, as has been described in this report, the catalyst to develop sustainability plans at the city level has often come from the feeling that increased traffic or road construction is eroding the quality of life. As such, the social dimension of sustainability is a key motivator of change and an important element for sustaining and maintaining support for any future investment. Therefore, additional attention should be paid to developing the analytical tools to consider it more fully and include in CBA.

8.3.4 Needs for Future Development—Cost Analysis

Table 43 shows the needs identified for future development to enable LCCA, LCA, and CBA to better support TBL sustainability.

Table 43. Needs for future development—cost analysis.

Development Needs	Description
Consensus on the range of impacts to be included	As with sustainability rating systems and ROI, there needs to be a consensus on the items that should be included in sustainability. In particular, the use of whole system design should be considered. Additional research is needed to identify potential elements and develop a consensus around these elements.
Accepted definitions of impacts and methodologies for estimating those impacts	Following on from the above issue, there needs to be additional research to define what is included in cost categories and to establish a methodology for estimating and monetizing costs associated with nonmarket elements (e.g., environment and society) or to develop alternative well-accepted measures.
Consensus as to a meaningful discount rate or methodology dealing with intergenerational costs and benefits that specifically express the value of future costs and benefits	As with ROI, a critical element of sustainability is the concern for long-term or intergenerational benefits. A new method of estimating long-term costs and benefits (perhaps using ecological models) or a more meaningful discount rate system needs to be developed. Additional research is needed to resolve this issue.
Clear understanding of methods of distributing costs and how investment decisions will impact different groups	Equity is a key issue for sustainability. In a representative democracy like the United States, no government program can be indifferent to where or when, or by whom, costs and benefits are experienced. There needs to be a consensus as to how equity issues should be addressed from a geographic, social, and temporal basis. Additional research is needed to resolve these issues and help identify the data needed and methodology to be used.
Consensus on valuation of social impacts	The social elements of the TBL are difficult to define and measure. Additional research will have to be developed to determine how to define, measure, and monetize this element of the TBL.

CHAPTER 9

Addressing TBL Sustainability—Now and in the Not-Too-Distant Future

Today, the policy, governance, funding flow, and decisionmaking challenges of TBL sustainability are daunting. Some thought leaders in the transportation sector are uncomfortable with the implications of managing transportation within a sustainable society policy system. In the prior chapter, the research team identified significant challenges and development needs facing application of key models and "must have" analysis methods that decisionmakers and managers will certainly need to navigate in a policy system based on TBL sustainability as an organizing principle. Nevertheless agencies in the United States and around the world have undertaken many sustainability initiatives that are advancing sustainability objectives. Progress is being made, but it remains primarily at the programming and project delivery functional levels, focused on sustainable transportation. At this stage, the data and supportable models do not exist to link transportation investments to results at three bottom lines—nor to establish and communicate TBL strategy alternatives simply and clearly to the public and among high-level decisionmakers.

However, there is good reason to believe that, via dramatic technological advances over the next 10 years, the data and TBL modeling challenges seen today will greatly diminish. This will dramatically transform the ability to understand and make the informed high-level TBL decisions with confidence, and with the support and acceptance of the public. The research team envisions major technological and scientific advances in four critical areas:

- Improved sensor technology, rapid data capture, data mining, analysis, and processing of "big data"
- Development of more powerful intelligent computing and "learning models" for decisionmaking
- Continued rapid advancement in interpersonal communications, networking capabilities, social media, and information dissemination to greatly facilitate engagement of the public
- Much greater scientific and public understanding of the relationship between transportation and the economy, society, and the environment

Each of these areas is discussed in the following sections.

9.1 Improvement in Sensor Technology and Omnipresent Data Collection

"Big data" refers to the collection of data sets so large and complex that it becomes difficult to process using conventional database structures and data management tools. Every day modern sensor and data collection tools collect, manipulate, and store enormous quantities of data. Business, defense, energy management, meteorology, genomics, complex physics simulations,

and biological and environmental research now regularly deal with petabytes to exabytes of data. The world's technological per-capita capacity to store information has roughly doubled every 40 months since the 1980s such that now 2.5 quintillion (2.5×1018) bytes of data are created every day (IBM, n.d.). Furthermore, the rate of big data growth is accelerating. Of the total data existing in the world today, more than 90 percent has been created in the last 2 years.

Data sets are growing in size in part because they are increasingly being gathered by ubiquitous information-sensing mobile devices, aerial and space-based sensory technologies (remote sensing), software logs, cameras, microphones, radio-frequency identification readers, and wireless sensor networks. In addition, the emergence of connected vehicles and smart infrastructure means that the transportation system is about to become a major supplier of big data. Data from connected vehicles alone will add exabytes of data to the data stream and transport the potential for managing the transportation system to reduce its environmental footprint. Table 44 shows some examples of these technologies, which are currently available or under development. As they are implemented, these technologies will radically increase the data available to transportation managers and increase managers' ability to understand the impacts of vehicle operations (e.g., private automobiles, transit, and trucks) on the environment.

In addition, a new generation of environmental sensors is emerging that will dramatically increase our understanding of how the environment is changing. Environmental sensor networks are rapidly evolving from passive logging systems that require manual downloading, into intelligent sensor networks that compose a network of automatic sensor nodes and communications systems which actively communicate their data to a sensor network server where this data can be integrated with

Table 44. Connected-vehicle technologies that will have positive environmental impacts.

Technology	Description
Eco-Approach and Departure at Signalized Intersections	The Eco-Approach and Departure at Signalized Intersections application uses wireless data communications sent from roadside equipment to vehicles and encourages green approaches to signalized intersections.
Eco-Traffic Signal Timing	The Eco-Traffic Signal Timing application is similar to current adaptive traffic signal control systems; however, the application's objective is explicitly to optimize traffic signals for the environment rather than the current adaptive systems' objective.
Eco-Traffic Signal Priority	The Eco-Traffic Signal Priority application allows either transit or freight vehicles approaching a signalized intersection to request signal priority.
Eco-Ramp Metering	The Eco-Ramp Metering application determines the most environmentally efficient operation of traffic signals at freeway on-ramps to manage the rate of entering automobiles.
Connected Eco-Driving	The Connected Eco-Driving application provides customized real-time driving advice to drivers, allowing them to adjust behaviors to save fuel and reduce emissions.
Multimodal Traveler Information	The Multimodal Traveler Information application provides pre-trip and en route multimodal traveler information to encourage transportation choices with reduced environmental impacts.
Dynamic Eco-Routing	The Dynamic Eco-Routing application determines the most eco-friendly route, in terms of minimum fuel consumption or emissions, for individual travelers. This application also recommends routes that produce the fewest emissions or reduce fuel consumption based on historical, real-time, and predicted traffic and environmental data.
Eco-Integrated Corridor Management Decision Support System	The Eco-Integrated Corridor Management Decision Support System application involves using historical, real-time, and predicted traffic and environmental data on arterials, freeways, and transit systems to determine operational decisions that are environmentally beneficial to the corridor. The Eco-Integrated Corridor Management Decision Support System is a data-fusion system that collects information from various multimodal systems.

other environmental data sets. The sensor nodes can be fixed or mobile and range in scale appropriate to the environment being sensed. For example, large-scale single-function networks tend to use large single-purpose nodes to cover a wide geographical area. Localized multifunction sensor networks typically monitor a small area in more detail, often with wireless ad hoc systems. In the future, sensor networks will integrate these three elements (heterogeneous sensor networks). The emergence of the cloud and real-time integration and analysis means that this data can be analyzed in real time to identify environmental trends and events [see Hart and Martinez (2006)]. These networks are creating a revolution in earth sciences that is likely to transform understanding of the interactions between the human and natural world over the next decades.

In addition, next generation sensors are emerging that may further enhance the ability to sense the environment. For example, the Defense Advanced Research Projects Agency (DARPA) is funding research into "smart dust," a miniature wireless node that uses microelectromechanical sensors on a cubic millimeter scale [see Pister (1997)]. Billions of these micro sensors could be introduced into the environment to sense changes in environmental conditions and changes. Larger static sensors (approximately one centimeter long) could also be built specifically for an environment under investigation and embedded in the environment to track environmental changes [see Hart and Martinez (2006)].

In addition, big data can provide much more information on economic and social conditions. Currently national income accounts (the basis of any economic model) rely on data that is at least 3 months out of date. GDP growth rates, employment data, and price information are frequently in error and must be adjusted or corrected months after the first information is released. Real-time data offers the prospect of a more accurate, deeper understanding of economic impacts. Simultaneously new data collection and analysis methods related to social behavior offer the prospect of a better understanding of how people respond to specific changes in their environment (Madan et al., 2010).

Taken together, these trends suggest that over the next 30 years, there is likely to be an explosion of data concerning transportation, economic, environmental, and social phenomena. This opens up the possibility of a better ability to understand, design, and operate transportation systems to optimize sustainability. One of the key requirements will be the development of processing capabilities that can analyze and understand the implications of this data. This issue is discussed in the next section.

9.2 Improved Computing Power, Advanced Analytics, and Intelligent Analysis and Modeling

Along with increases in data, there has been a steady ongoing increase in processing power. Moore's law, the observation that over the history of computing hardware, the number of transistors on integrated circuits doubles approximately every 2 years, has meant that huge increases in computing power have occurred and continue to occur. While it is generally acknowledged that the limits of Moore's law are being reached if silicon-based technology continues to be used, technologies such as optical computers, quantum computers, and DNA computing offer the possibility of continuing to expand into the future [see Peckham (2012)].

The futurist Ray Kurzweil agrees that by 2019 the current strategy of ever-finer silicon photolithography will have reached its maximum development but speculates that this does not mean the end of Moore's law:

> "Moore's law of integrated circuits was not the first, but the fifth, paradigm to forecast accelerating price–performance ratios. Computing devices have been consistently multiplying in power (per unit of time) from the mechanical calculating devices used in the 1890 U.S. Census, to [Newman's] relay-based '[Heath]

> Robinson' machine that cracked the Lorenz cipher, to the CBS vacuum tube computer that predicted the election of Eisenhower, to the transistor-based machines used in the first space launches, to the integrated-circuit-based personal computer" (Kurzweil, 2001b).

Kurzweil speculates that, given past performance and the demand for expanded data processes in the emerging era of big data, a replacement technology will arrive that will continue Moore's law long after 2020.

More hardware does not by itself provide machine intelligence. However, it contributes to the development of machine intelligence. For example, cheap, fast computing resources allow researchers to experiment with new algorithms and data mining and correlation techniques to achieve improved machine intelligence or to gain new insights by processing massive data sets (Muehlhauser and Salamon, 2012).

There have been recent breakthroughs in artificial intelligence (AI; e.g., the development of Gödel machine formulations and AIXI[11]), and the near future promises significant breakthroughs in everyday application of AI (e.g., natural language recognition and translation, visual recognition, automated decisionmaking), massive data sets, progress in cognitive science and neuroscience, accelerating scientific development, and substantial economic incentives (Muehlhauser and Salamon, 2012). All of these developments suggest that conceivably human-level AI could be approached within the next 50 to 100 years. Moreover the development may lead quickly to machine super-intelligence (or so-called "strong AI"), that is, an intelligence that surpasses human intelligence and is capable of expanding its own intelligence in the future.

Such systems would have dramatic effects on the ability to understand and manage the interaction between transportation and the TBL. Combined with omnipresent data, it would be possible for such systems to immediately model and understand the relationship between the human and environmental system and determine the impacts of individual changes on the system as whole.

This is not science fiction. Even now, the beginnings of such systems exist. Advanced analytic systems used in business and government combine multivariate statistical analysis, complex multistate simulation, machine learning, neural networks, text analytics, advanced data visualization, and other advanced data mining techniques to create near-intelligent decision supports systems. These systems can perform the following functions:

- **Analyze and explain complex hidden trends:** Through the use of statistical analysis and modeling and simulation, advanced analytics provides a mechanism to dynamically analyze and understand trends and develop explanations for them.
- **Optimize operations and understand relationships:** Advanced analytics helps analysts understand the relationships between variables, identify causality and system drivers, and optimize processes to increase program performance and goal attainment.
- **Predict outcomes and identify risks:** By applying their understanding of past trends and the relationships between variables, analysts are able to develop a predictive model to identify potential outcomes in real time and create a risk-based, probabilistic forecast of future states.

[11] AIXI is the first mathematical theory of optimal Universal Artificial Intelligence. It was developed in 2002 and represents a major breakthrough in understanding automated decisionmaking that solves the problem of sequence prediction for unknown prior distribution. A Gödel machine is a mathematical formulation of a rigorous, general, fully self-referential, self-improving, optimally efficient problem-solving system. The model allows for a set of self-referential formulas that rewrites any part of its own code as soon as it has found a proof that the rewrite is useful, where the problem-dependent utility function, the hardware, and the entire initial code are described by axioms encoded in an initial proof searcher which is also part of the initial code. The searcher systematically and efficiently tests computable proof techniques (programs whose outputs are proofs) until it finds a provably useful, computable self-rewrite.

- **Test assumptions, proposed policies, and alternative program models:** Advanced analytics allows the creation of virtual worlds where assumptions concerning an analysis can be tested and the limitations and weaknesses of current models can be understood. In addition, it provides a sandbox where analysts can test proposed policies and/or alternative program models and assess impacts.
- **Visualize data:** Advanced analytics allows previous numeric or quantitative data to be turned into a meaningful visual representation of the underlying order and regularity of the data.

The combination of these tools and big data brings very close the kind of analytics required to properly understand and model the relationship between transportation and its impacts on the TBL. Given the development of AI and big data, it is quite possible that over the next decades there will be an explosion in the ability of automated systems to understand and manage sustainability. The cost of such systems (considering the continuing decline in technology and storage costs) may be such that the ability to manage sustainability in the future would be in the hands of almost every transportation agency, partner agencies, and the public.

9.3 Rapid Advancement in Networking Capabilities and Information Dissemination Leading to Improved Understanding of Relationships between Transportation and the Economy, Society, and the Environment

While increased data and improvements in machine intelligence and analytics may provide the potential to better understand the impacts of transportation and other human systems on sustainability, a strong theoretical basis to model these interactions is still lacking. For example, economics is one of the most developed of the social and behavioral sciences and, due to the money that is associated with financial modeling, has attracted considerable resources in recent years. However, understanding of economic behavior is extremely limited. Macroeconomic models rarely predict accurately and are dependent on multiple assumptions and preprocessed data analysis. New approaches such as agent-based, system-dynamic models offer hope of improving their predictive capability but basic mathematical and theoretical challenges still exist.

There is some hope that these challenges may be resolved. For example, the initiative known as the "Manhattan Projects for Economics" brings together physicists, mathematicians, and economists to work on extremely hard theoretical and computational problems in economics. The idea is that, because many of the challenges that economists face are similar to those that physical scientists have already encountered and resolved, the mathematical techniques and theoretical paradigms they have developed in resolving these challenges may provide insight into critical economic problems that economists are wrestling with [see Brown et al. (2008)]. For example, certain economic problems relating to competing multiple preferences may now be dealt with by infinite dimensional diff (S1) theory or Non-Abelian Gauge theory.

The emergence of dramatically faster scientific communication via the web, huge increases in the number of scientists and research as China and India develop, and the resources that are already available worldwide suggest that this synergy and interdisciplinary communication may lead to breakthroughs in multiple fields over the next 10 to 30 years. Combined with improvements in AI, processing power, and the availability of data, it is very likely that current TBL decision-support challenges may vanish. With that, direct and supportable understanding of the relationship between transportation and TBL sustainability will provide the tools needed to manage resources in

real time to optimize and improve TBL sustainability to the maximum practical extent, should the policy system call for that goal.

* * * *

Whatever the future may bring, one of the limiting factors will still be the challenge we have as a society in reaching wide consensus on the relative value of the three bottom lines. While we may understand better how transportation affects the environment or how managing resources today affects the viability of the future, debate on those values will continue. No matter how the bottom line values are set and what predictive models and machine intelligence may tell us of the future—we will always encounter societal decisions that require us to assess how much we value the well-being of our next generation versus our own demands for quality of life.

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APPENDIX A

Detailed Descriptions of Drivers

Demographic Factors (population size, characteristics, and magnitude)

This driver involves the size, distribution, and characteristics (e.g., age, sex, and ethnicity) of the U.S. population.

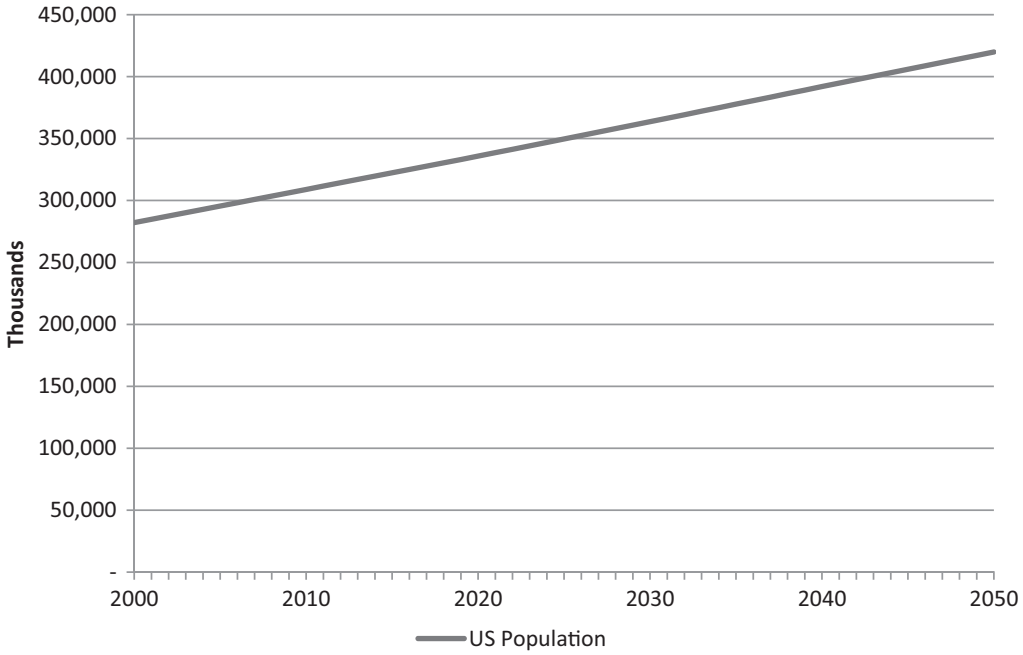
Significance

The size, geographic distribution, and characteristics of the U.S. population are likely to be a major factor influencing the resources available to state transportation agencies, transportation demand, and the opportunities and challenges facing state transportation agencies.

Trends

The U.S. Bureau of the Census provides detailed projections of the U.S. population between 2000 and 2050. Figure A-1 shows the overall projection. As shown in the figure, the U.S. Bureau of the Census projects that the U.S. population will increase from approximately 282 million in 2000 to approximately 419 million in 2050. With the population currently estimated to be 308 million in 2010, this means that approximately 111 million people will be added between 2010 and 2050.

These population projections were made using the cohort-component method, which makes assumptions about the components of population change (e.g., fertility, mortality, international migration) to project population by age and sex [for a more detailed discussion of the cohort-component method and the assumptions about the components of population



Source: U.S. Bureau of the Census (2000).

Figure A-1. U.S. Bureau of the Census population projections, 2000–2050.

change, see U.S. Bureau of the Census (2000)]. The following describes these assumptions briefly:

- **Fertility assumptions:** The fertility assumptions use a total fertility rate (average number of lifetime births per 1,000 women implied by age-specific fertility rates) of 2,048 in 1999; 2,207 in 2025; and 2,219 in 2050 [Note: Fertility increases largely as a result of immigration, because immigrants tend to be younger and have larger families; U.S. Bureau of the Census (2000)].
- **Mortality assumptions:** The mortality values assume that average life expectancy at birth will increase gradually from the 1999 values of 74.1 years for the male population and 79.8 years for the female population to the 2050 values of 81.2 years for the male population and 86.7 years for the female population (U.S. Bureau of the Census, 2000).
- **Migration assumptions:** The basic international migration assumptions made by the U.S. Bureau of the Census include assumptions about levels of immigration (both legal and illegal) of foreigners to the United States and about rates of emigration from the United States. Annual net immigration (i.e., immigration minus emigration) is estimated to be 996,000 in 2025 and 1,097,000 in 2050.

In terms of the age distribution of the population, the U.S. Bureau of the Census predicts that the population will age over the period 2000 to 2050. As Figure A-2 and Table A-1 show, the population over 60 is expected to increase from 16 percent to 26 percent between 2000 and 2050.

A major uncertainty in these population estimates is the distribution of population within the United States. The following section discusses this issue.

Distribution of Population within the United States

In terms of the distribution of population throughout the United States, there are a number of alternative scenarios. One of the most common assumptions about the distribution of the future population is the so-called "megaregion" model. Under this model, analysts note that if current economic and population trends continue, by 2050, more than 80 percent of the nation's population, economic activity, and jobs will be centered in megaregions (Regional Plan Association, 2006).

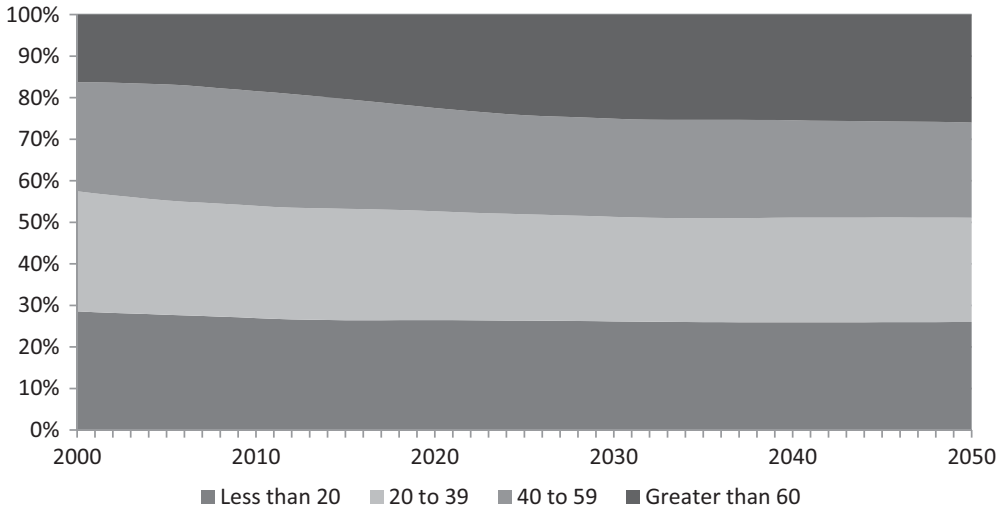


Figure A-2. U.S. Bureau of the Census population projections—age structure.

A megaregion is a geographically clustered network of cities and suburban areas that are brought together via shared infrastructure, economic interests, settlement and land use patterns, and a common environmental, geographical, and topographical focus (Regional Plan Association, 2006). Megaregions are not megacities (i.e., a city with a population of greater than 10 million) or single, uninterrupted urban areas (Anonymous, 2006). In fact, a megaregion may contain a number of cities and a mixture of different land uses (e.g., densely populated urban centers, suburban sprawl, exurban communities, small towns, and even rural areas). As an example, the northeast megaregion normally extends from Boston, Massachusetts, to Washington, D.C., or Richmond, Virginia. Within that region, there are many cities, towns, suburbs, and rural areas, but they can be considered a single region because they rely on key elements of common infrastructure and economic interests. In this case, the I-95 corridor, parallel rail networks, the electricity grid, and trade flows between the cities and towns tightly connect the people and environment of this megaregion.

The existence of megaregions in some of the scenarios in this report does not mean that cities and regions not included in the megaregions will decline or cease to exist. In all of the developed scenarios for the future, megaregions are ***not*** expected to "take" more population from other parts of the United States, but, as magnets for trade and economic growth, they are likely to become richer and more interconnected at a faster rate than other areas. These ideas are consistent with the literature, which predicts that numerous cities and small towns outside the megaregions will continue to grow and maintain vibrant economies.

There is dispute about the number and location of megaregions in the United States. Virginia Tech's Metropolitan Institute and the Regional Plan Association conducted the most well-known efforts to describe and define the megaregions using slightly different

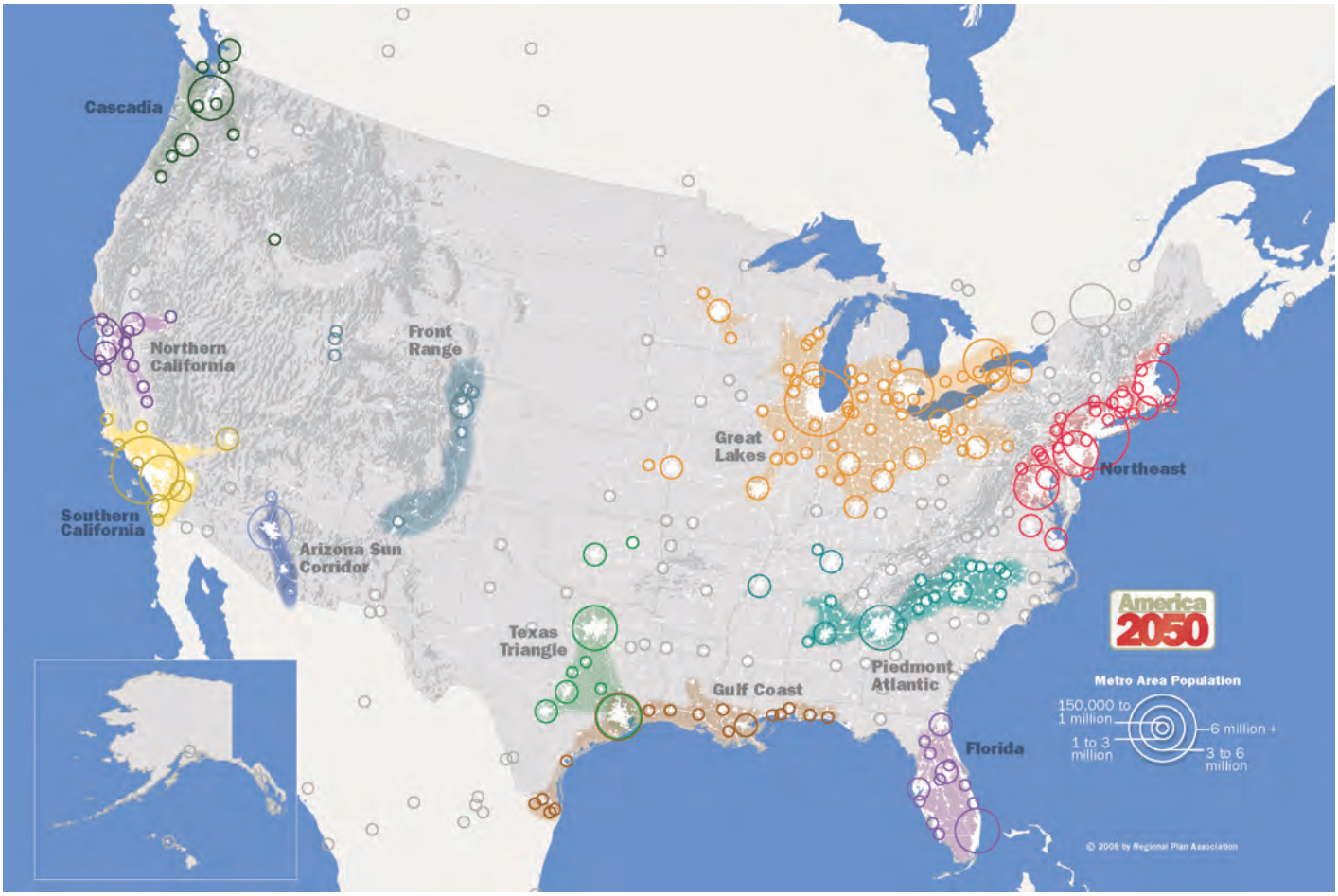
Table A-1. Proportion of population in different age cohorts, 2000 and 2050.

	Proportion of Population in Age Cohort			
Year	<20	20–39	40–59	>60
2010	29%	29%	26%	16%
2050	26%	25%	23%	26%

Source: U.S. Bureau of the Census (2000).

methods (Regional Plan Association, 2006). Figure A-3 shows the megaregions identified by the Regional Plan Association; Figure A-4 shows megaregions identified by the Metropolitan Institute. As can be seen, there is a close correspondence between the megaregions identified by the two groups.

A potential counter trend is that technology advances and sociocultural preference may lead to greater decentralization (Kotkin, 2010). Under this scenario, population growth will occur in small towns, suburbs, and secondary cities outside the megaregions. This scenario notes specifically that despite recent increases in central city population over the past 20 years, most of the growth in the United States has been in the suburbs that surround the growing cities of the South and West—in places that followed the Los Angeles sprawl model of urban planning, such as Houston, Texas, and Phoenix, Arizona. Similarly, rural areas and small towns will continue to grow as technology allows people greater freedom in deciding where they live. Given that Americans have consistently shown a preference for single-family homes, ample yard space, and the suburban lifestyle (i.e., people seeking a more family-friendly environment with less congestion and crime than in inner cities, lower property prices, and decentralization of economic life), if technology and the economy allow people the freedom to continue this behavior, they likely will. In addition, the demand for biofuels, as well as for solar and wind energy, will make rural areas economically viable, presenting new opportunities for economic development outside the megaregions.



Source: Regional Plan Association (2008).

Figure A-3. Megaregions in 2050 as identified by the Regional Plan Association.

Source: Georgia Tech Research Corporation (2011).

Figure A-4. Megaregions in 2050 as identified by the Metropolitan Institute.

Using these two scenarios, the research team identified two potential paths forward for the United States:

- **Megaregion Future:** Population and economic activity continue to concentrate in megaregions that are bound together with increasing infrastructure and economic ties.
- **Decentralized Future:** Population is distributed more evenly across the nation, with a revival in suburbs, small towns, and medium-size cities as technology allows people to live and work where they want.

Combining these ideas with our projections of population growth, the research team created a matrix that shows different potential outcomes of different population growth and distribution trends (Table A-2) and describes how each potential outcome might look and the factors related to that outcome.

Economic Growth and Public-Sector Spending on Transportation

This driver involves the future patterns of economic growth (e.g., GDP, inflation, investment, employment, income growth) and public-sector spending (e.g., federal, state, and local) on transportation.

Significance

The broad increase in U.S. GDP is generally considered to be a major determinant of the resources that will be available to address the major challenges that federal, state, and local transportation agencies will face between 2010 and 2050. Based on the record of the last century, rapid economic growth has transformed American society and culture, and radically defined its ability to address major societal challenges (Lindsey, 2007).

Table A-2. Potential outcomes related to population.

Size of Population by 2050*	Population Distribution	
	Megaregions	Decentralized
Low (399 million)	• Low economic growth in the United States relative to other countries leads to lower net migration. • Fertility and mortality patterns follow expected trends. • Population continues to follow current spatial distribution tendencies, with population concentrated in megaregions.	• Low economic growth in the United States relative to other countries leads to lower net migration. • Fertility and mortality patterns follow expected trends. • Technology allows increased freedom for individuals to live and work where they wish, leading to rapid decentralization and growth in small towns, smaller cities, and suburbs. • Increased investment in rural industries (e.g., biofuels, extractive industries) leads to increased growth in rural areas.
Medium (419 million)	• Economic growth continues along anticipated lines, causing net migration to follow anticipated patterns. • Fertility and mortality patterns follow expected trends. • Population continues to follow current tendencies with population concentrated in megaregions.	• Economic growth continues along anticipated lines causing net migration to follow anticipated patterns. • Fertility and mortality patterns follow expected trends. • Technology allows increased freedom for individuals to live and work where they wish, leading to rapid decentralization and growth in small towns, smaller cities, and suburbs. • Increased investment in rural industries (e.g., biofuels, extractive industries) leads to increased growth in rural areas.
High (458 million)	• Better-than-expected economic growth causes increases in net migration. • Fertility and mortality patterns follow expected trends. • Population continues to follow current tendencies with population concentrated in megaregions.	• Better-than-expected economic growth causes increases in net migration. • Fertility and mortality patterns follow expected trends. • Technology allows increased freedom for individuals to live and work where they wish, leading to rapid decentralization and growth in small towns, smaller cities, and suburbs. • Increased investment in rural industries (e.g., biofuels, extractive industries) leads to increased growth in rural areas.

*Population estimates are from U.S. Bureau of the Census (n.d.).

Other TRB reports relevant to this driver

This section provides an overview of economic issues. *NCHRP Report 750, Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment* provides a detailed discussion of economic issues as they affect freight, including potential broad economic changes and freight and transportation energy scenarios. At the time of this writing, these scenarios were not available to the research team.

Readers should note that this section focuses on general economic trends as they affect the challenges and opportunities that state transportation agencies may face, rather than freight-specific changes.

Trends

Based on historical growth in U.S. GDP over the past century and half, the U.S. economy has grown at an average rate of more than 3 percent per year (Ridely, 2010). The consistent and robust strength of this trend gives the United States a reasonable starting point for future economic growth predictions. To create a picture of what future economic growth might look like, the research team used the U.S. Department of Energy's (DOE) National Energy Modeling System (NEMS) to develop a series of economic scenarios. The team used NEMS because it made possible the combining of economic projections with energy supply/demand scenarios. The NEMS Macroeconomic Activity Module (MAM) considers a series of macroeconomic indicators, including GDP, disposable income, value of industrial shipments, new housing starts, sales of new light-duty vehicles, interest rates, and employment. Key energy indicators fed back to the MAM include aggregate energy prices and costs. Using NEMS, the DOE created a series of different economic growth cases that can act as a benchmark for developing different future economic performance scenarios:

- **High-growth case:** Under this case, high growth rates for population (1.3 percent per year, compatible with the U.S. Bureau of the Census's "high-population" estimate) and labor productivity (2.4 percent per year, representing a relatively rapid improvement in technology) result in higher nonfarm employment (1.2 percent per year) and low unemployment. With higher productivity gains and employment growth, inflation and interest rates remain low, and consequently economic output grows at a higher rate than in the reference case (2.4 percent). Disposable income per capita increases by 1.82 percent per year. Figure A-5 shows this case along with the moderate- and low-growth cases.
- **Moderate-growth case:** This case builds projections from current anticipated economic conditions (compatible with the most recent U.S. Office of Management and Budget and Congressional Budget Office forecasts) that include the current recession and the prospects for a return to normal economic growth in the middle of the current decade. Under this case, nonfarm employment increases by 0.8 percent per year, and labor productivity by 2.0 percent per year. Economic output, as measured by real GDP, increases by 2.4 percent per year, and growth in real disposable income per capita averages 1.8 percent per year (see Figure A-5).

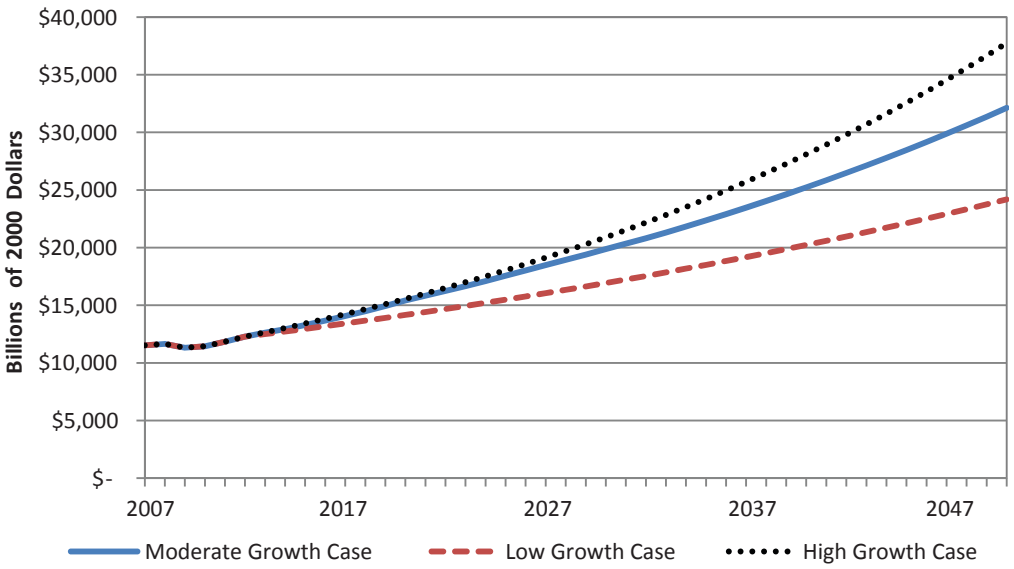


Figure A-5. High, low, and medium economic growth case from NEMS.

- **Low-growth case:** The low economic growth rate case expresses a noncrisis scenario with overall depressed growth. This case assumes lower growth rates for population (compatible with low estimates from U.S. Bureau of the Census projections) and labor productivity (1.5 percent per year, representing a relatively slow improvement in technology), resulting in lower nonfarm employment (0.4 percent per year), higher prices and interest rates, and lower growth in industrial output. In the low economic growth case, economic output, as measured by real GDP, increases by 1.8 percent per year, and growth in real disposable income per capita averages 1.7 percent per year (see Figure A-5).

These projections are by no means the only visions of future GDP. There is a broad body of literature that presents both more optimistic and more pessimistic scenarios. At the negative extreme, numerous scenarios predict a future of ongoing depression or economic collapse (Levine, 2008). Specifically, resource exhaustion (e.g., peak oil), increasing environmental pressures, and/or failure to deal with long-term economic and social problems may lead to lower than expected growth and recurrent recessions. However, there is little hard analysis of the impact of these drivers. The analysis that does exist depends on numerous assumptions. For example, the Stern Report, developed by former World Bank chief economist Nicholas Stern and undertaken on behalf of the United Kingdom (UK) government, estimates the cost of climate change could range from 5 percent to 20 percent of global GDP by 2050; however, stabilization at 500 to 550 parts per million (ppm) carbon dioxide equivalents (CO_2e, a measure of the contribution of six key GHGs) will cost the global community approximately 1 percent of GDP by 2050 (Stern, 2006). More recent analyses of the impact of geography and population distribution have estimated it to be on the order of 1.7 percent to 3 percent of GDP by 2050 (Nordhaus, 2006). These analyses, however, consider only one major crisis—the impact of climate change. For example, one analysis of the impact of a peak oil reduction of 30 percent between 2006 and 2050 predicts an 11 percent decline in U.S. per capita GDP (Chefurka, 2007).

All these analyses differ in terms of their methodology, assumptions, and drivers; however, to include a credible worst case, the research team plotted a series of potential outcomes and then averaged these scenarios to create a worst-case outcome (approximately 8 percent). For comparison, at the depth of the current recession, GDP fell by 6.1 percent. This outcome suggests a decade-long economic recession in which every year is worse than the previous year.

It should be stressed that a trend of this magnitude has *never* been seen in any developed country. Even depressions in emerging economies rarely experience long-term GDP declines, and they rarely last longer than 10 to 20 years. More typically, emerging economies experience rapid cycles of booms and busts (Federal Reserve Bank of Minneapolis, 2007). Thus, despite the widespread negative and pessimistic literature, the worst-case outcome here is unprecedented; nothing in U.S. history or the broader history of the industrialized world is remotely like this outcome.

Figure A-6 presents these projections. As shown, these projections show an initial decline as the United States continues to experience effects from the financial crisis of 2008, and then a return to growth, which is subsequently interrupted by a range of challenges, from climate change to resource shortages.

Alternatively, there are other visions where economic growth increases dramatically. For example, current world economic growth has created a situation in which world wealth

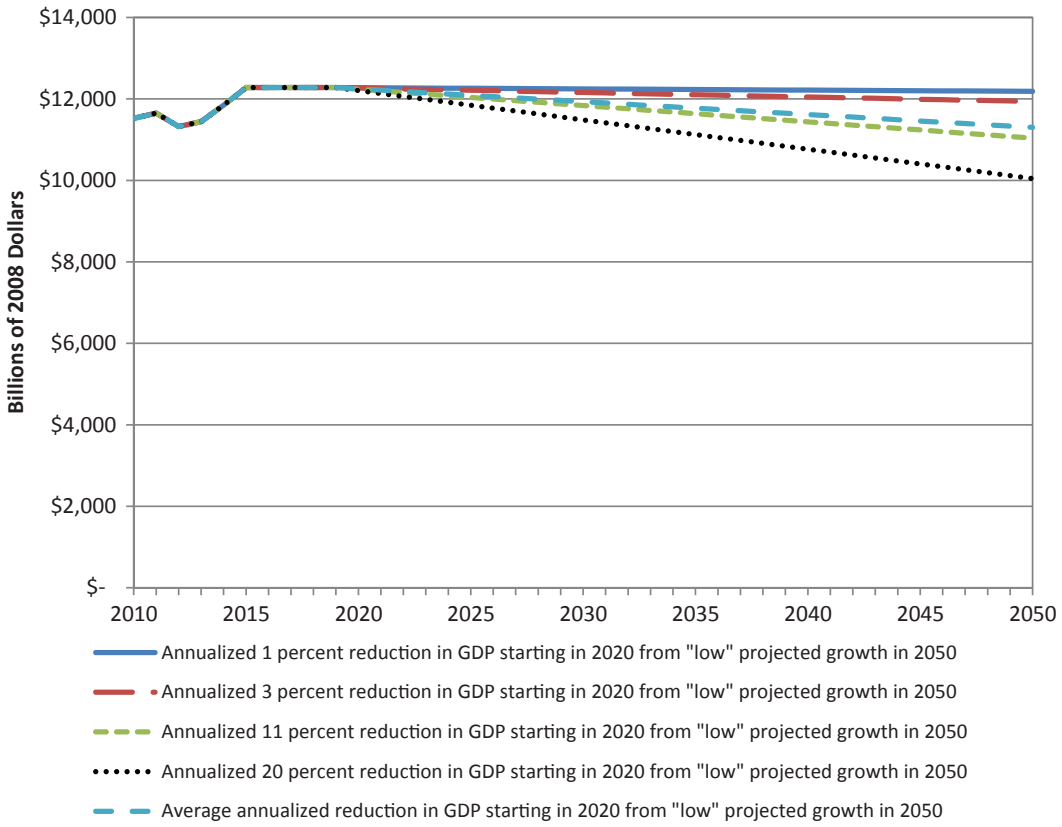
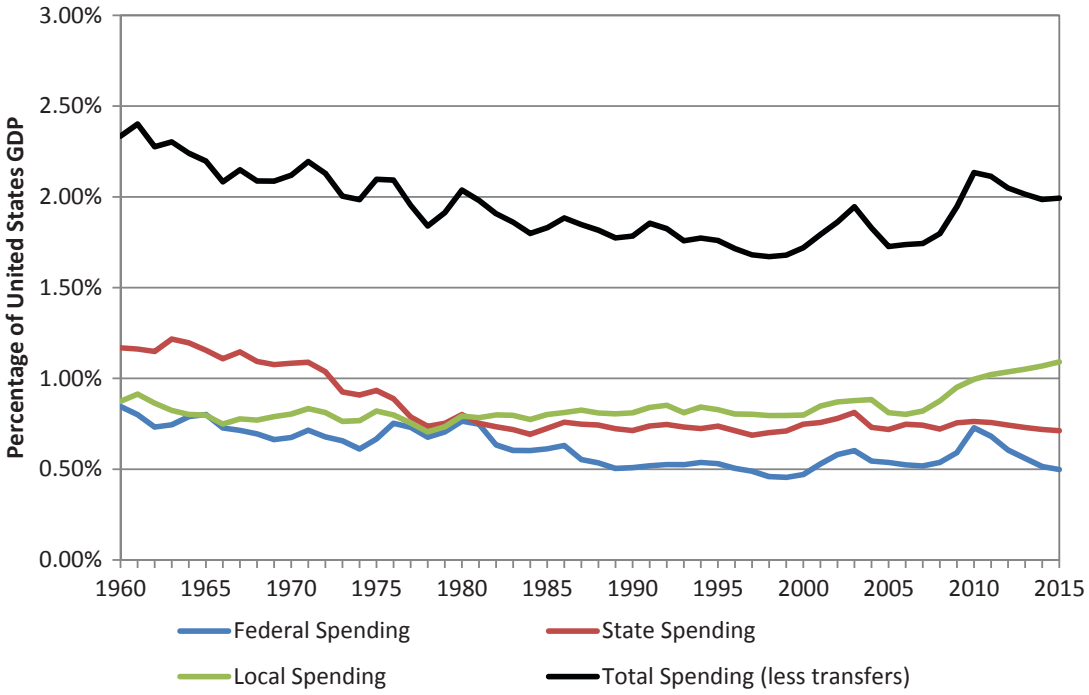


Figure A-6. Worst-case GDP outcomes.

(adjusted for inflation) doubles every 15 years (Hanson, 2008). Given current trends in technology (e.g., developments in artificial intelligence, computer processing speed, nanotechnology, robotics, biotechnology, and automation); some futurists predict that society is on the verge of a great jump forward or rapid acceleration in economic growth (analogous to the Industrial or even the Agricultural Revolutions). This phenomenon, known in the literature as "the singularity," predicts an increase in technology-driven economic growth such that world wealth would double every 5 years—or possibly every 2 weeks. Although it is possible that such phenomena could occur, it is not included in the outcome analysis because the various expert reviews the team conducted considered them too extreme and impractical for the analysis.

GDP and personal income are only one measure of the resources that will be available to state transportation agencies. Another measure is the level of resources that will be devoted to public-sector activities, including transportation. Figure A-7 summarizes federal, state, and local spending on transportation between 1960 and 2015 (projected) in nominal dollars and as a percentage of GDP (Note: total figures include statutory federal transfers such as Medicare and Social Security). Table A-3 summarizes the percentage of GDP for each level of government invested in transportation between 1960 and 2015. As shown, despite numerous fluctuations, the proportion of U.S. GDP invested in transportation has remained relatively stable at 1.95 percent (never more than 2.4 percent; never less than 1.67 percent). Given the long-term nature of this trend and assuming that transportation remains in the same position relative to other public-sector priorities, it is likely that this trend will continue



Source: Bloomberggovernment.com

Figure A-7. Transportation spending from federal, state, and local governments, 1960 to 2015 (estimated).

into the future. Appendix B provides detailed backup data and assumptions related to this analysis.

Several experts on the research team interviewed for the project suggested that past trends for federal, state, and local transportation spending are not useful predictors of future spending patterns. Specifically, they cited that a shift to user fees and congestion pricing mechanisms would transform the funding positions for state and local governments. This assumes that there will be public and political support for a shift to user fees. It is possible that this may occur; however, it is equally possible that public resistance to user fees and congestion pricing may prevent a shift to this form of transportation funding. It is also possible that user fees and congestion pricing will only offset the losses experienced by federal and state governments in collecting gas taxes from increasingly more fuel-efficient vehicles.

Based on this analysis, the research team identified potential outcomes and trends for the period 2010 to 2050, as shown in Table A-4.

Table A-3. Average percentage of GDP invested in transportation by all levels of government, 1960 to 2015 (estimated).

Level of Government	Percentage of GDP
Federal Government	0.62%
State Government	0.84%
Local Government	0.84%
Total (removes federal transfers to state and local governments)	1.95%

Table A-4. Potential economic growth and transportation spending outcomes, 2010 to 2050.

Potential Outcome	Growth of GDP	Spending on Transportation	User Fees and Congestion Pricing	
			Public Accepts	Public Rejects
Economic Decline Case	After 2020, GDP falls by 8% over the next 30 years.	Spending on transportation for federal, state, and local governments stays at the historic average, with the federal government gradually reducing its role over time.	Public and political acceptance of user fees and congestion pricing leads to a system where funding gaps are filled by user fees.	Public and political rejection of user fees and congestion pricing prevents the emergence of a system where user fees cover funding gaps.
Low-Growth Case	Economic output, as measured by real GDP, increases by 1.8% per year. Note: 1.8% is an average from the entire period. This means that there might be rapid growth in one period that will be lost in later periods.	Spending on transportation for federal, state, and local governments stays at the historic average, with the federal government gradually reducing its role over time.	Public and political acceptance of user fees and congestion pricing leads to a system where funding gaps are filled by user fees.	Public and political rejection of user fees and congestion pricing prevents the emergence of a system where user fees cover funding gaps.
Moderate-Growth Case	Economic output, as measured by real GDP, increases by 2.4% per year.	Spending on transportation for federal, state, and local governments stays at the historic average.	Public and political acceptance of user fees and congestion pricing leads to a system where funding gaps are filled by user fees.	Public and political rejection of user fees and congestion pricing prevents the emergence of a system where user fees cover funding gaps.
High-Growth Case	Economic output increases by an average of 3.8% per year.	Spending on transportation for federal, state, and local governments stays at the historic average.	Public and political acceptance of user fees and congestion pricing leads to a system where funding gaps are filled by user fees.	Public and political rejection of user fees and congestion pricing prevents the emergence of a system where user fees cover funding gaps.

Other TRB reports relevant to this driver

This section provides an overview of energy issues. *NCHRP Report 750, Volume 5: Preparing State Transportation Agencies for an Uncertain Energy Future* provides a detailed discussion of energy issues, including potential transportation energy scenarios. At the time of this writing, these scenarios were not available to the research team. As a result, the team developed independent energy outcomes that are based on more general energy and transportation information. Readers should note that this section focuses on general energy trends rather than on a detailed analysis of transportation energy scenarios.

Energy (includes transportation energy uses and fuel prices)

This driver involves the future patterns of energy use and future transportation fuel prices.

Significance

The availability of traditional and new fuels is believed to be one of the most important factors in the future viability of the U.S. economy and the options open to U.S. transportation planners (Spiegel et al., 2009; Paul, 2009).

The Energy Information Administration (EIA), every year, uses the NEMS to produce a series of forecasts of energy use to the year 2035. These outcomes seem relatively conservative, but they present a dramatic range. The research team extended these forecasts out to 2050 using NEMS and modified them based on interviews with SMEs and several SME panels. Based on these trends, the team identified a series of outcomes that represent different levels of GDP, population, technology development, and energy choices and assumptions concerning the energy market. The research team used these parameters to develop low, medium, and high outcomes. Appendix C shows the data behind each outcome in detail (i.e., production, import, export, and fuel usage) for the period 2010 to 2050 [see U.S. Energy Information Administration (2010) for a full discussion of the assumptions in this section]. In addition, the research team used NEMS to develop an additional set of outcomes based on:

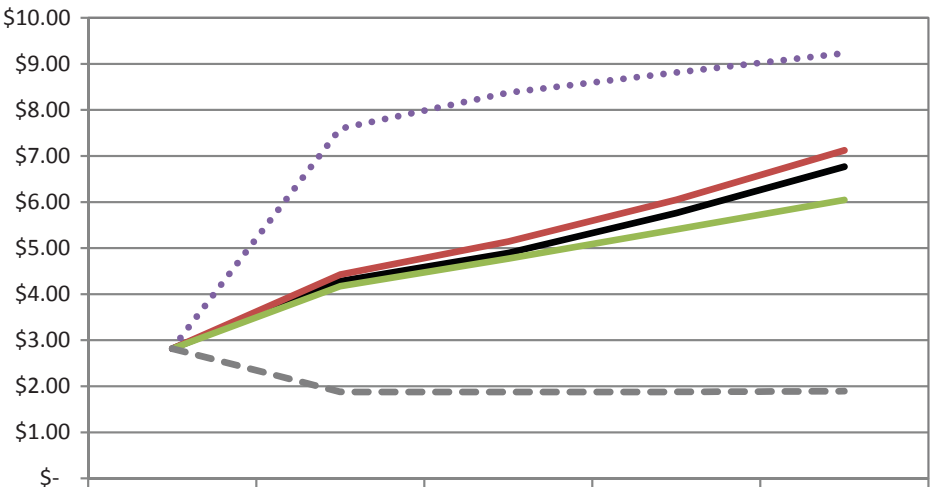
- Low versus high technology growth (technology assessments are consistent with those based on preliminary information from a draft of *NCHRP Report 750, Volume 5: Preparing State Transportation Agencies for an Uncertain Energy Future*)
- Low versus high oil-price growth.

NEMS produced the following estimates of future oil prices given the research team's GDP scenarios and DOE assumptions about future oil availability:

- **Moderate-Growth Case:** Assumes world light, sweet crude oil prices are about $133 per barrel (2008 dollars) in 2035.
- **High Oil-Price Case:** More pessimistic assumptions for economic access to non-OPEC resources and for OPEC behavior. Under this case, world light, sweet crude oil prices are about $210 per barrel (2008 dollars) in 2035.
- **Low Oil-Price Case:** More optimistic assumptions for economic access to non-OPEC resources and for OPEC behavior. Under this case, world light, sweet crude oil prices are $51 per barrel in 2035 (2008 dollars).

Figure A-8 combines all cases to show the different range of gas prices per gallon under these different outcomes [gasoline prices per gallon were calculated by the research team using the methodology described in Hamilton (2007)]. The high and low technology-growth fuel-use patterns closely resembled those generated in the high and low GDP-growth patterns. ***Economic growth appears to be a more important determinant of energy use than technology***. Thus, only the different GDP cases and oil-price cases are shown in Figure A-8 to reduce confusion. As shown, depending on the assumptions made, predicted gasoline prices per gallon in 2050 vary from $1.89 (low oil price) to $9.23 (high oil price) in 2008 dollars. Note: These prices assume a tax structure similar to that of today.

Booz Allen SMEs and external academics reviewed these trends and projections. Based on their inputs, Table A-5 was created to show a number of plausible energy outcomes related to the transportation sector and energy price projections.



	2010	2020	2030	2040	2050
Moderate GDP Growth Case	$2.82	$4.28	$4.89	$5.76	$6.77
High GDP Growth Case	$2.82	$4.42	$5.14	$6.05	$7.12
Low GDP Growth Case	$2.82	$4.17	$4.77	$5.41	$6.05
High Oil Price Case	$2.82	$7.60	$8.38	$8.82	$9.23
Low Oil Price Case	$2.82	$1.88	$1.87	$1.88	$1.89

(2008 Dollars, assumes 2008 Tax Mix)

Figure A-8. Projected price per gallon of gasoline for various GDP cases and oil–price cases.

Table A-5. Potential transportation energy usage and energy price outcomes, 2010 to 2050.

Potential Outcomes	Energy Usage	Fuel Price (using price of gasoline as indicator)
Low Growth	Petroleum and other carbon fuel remain the most important sources of fuel. Alternative fuels account for less than 16 percent of the transportation market. Electricity is a major energy source for surface transportation, but most still comes from coal and related fuels.	Gasoline prices are somewhat depressed, but world demand continues to push them to more than $6 per gallon.
Moderate Growth	Petroleum and other carbon fuel remain important sources of fuel, but alternative fuels account for 18 percent of the transportation market. Electricity is a major energy source for surface transportation. Some electricity still comes from clean coal and noncarbon sources.	Gasoline prices close to $7 per gallon.
High Growth	Petroleum and other carbon fuel remain important sources of fuel, but alternative fuels account for 20 percent of the transportation market. Electricity is a major energy source for surface transportation. Most electricity comes from clean coal and noncarbon sources.	Gasoline prices close to $7 per gallon.
High Oil Price	Petroleum and other carbon fuel remain the most important sources of fuel. Alternative fuels account for 20 percent of the transportation market. Electricity is a major energy source for surface transportation, and some comes from clean coal and noncarbon sources.	Gasoline prices close to $9 per gallon.

Climate Change, Environment, and Resource Use

Description

This driver involves future changes in the environment, specifically, climate change, impact of commerce and industry, related phenomena, other environmental changes, and resource availability and resource use.

Other TRB reports relevant to this driver

This section provides an overview of climate change issues. *NCHRP Report 750, Volume 2: Climate Change, Extreme Weather Events, and the Highway System* provides a detailed discussion of climate change issues. At the time of this writing, the scenarios developed as part of this project leading to the report were not available to the research team. This driver addresses broader environmental and resource use changes. Readers should note that this section focuses on general environmental and resource use trends rather than on a detailed analysis of transportation and climate change.

Significance

Climate change, environmental change, and resource availability are critical determinants of the ability of the economy to grow and flourish in the 21st century. In particular, the state of the environment will be a critical determinant of the challenges and opportunities that state transportation agencies face in supporting a sustainable transportation system and a sustainable society (Matsushita and Helten, 2001). These are serious challenges, but from the point of view of this project they are important only in the degree to which they might affect the ability of state transportation agencies to support sustainable transportation and a sustainable society. Based on the research team's analysis of the literature, most of these challenges have relatively limited direct impacts, but substantial indirect impacts, on transportation and state transportation agencies. For example, climate change directly affects transportation systems in a number of ways (see *NCHRP Report 750, Volume 2: Climate Change, Extreme Weather Events, and the Highway System*). Transportation also affects the environment, which in turn places additional demands on society's ability to manage and respond to transportation requirements. Figure A-9 provides an overview of this relationship. Thus, while there are numerous environmental challenges, the research team focused on the environmental challenges and trends that are most likely to affect state transportation agencies' ability to support a sustainable society.

Trends

The literature on environmental trends in the first half of the 21st century is wide and extremely diverse. The research team reviewed hundreds of books, reports, blogs, and articles that address this issue. On the basis of this literature review, the research team determined that views about the future of the environment and resources vary along two dimensions: management/planning and overall environmental outlook (see Figure A-10).

- **Environmental Outlook:** Futurist, scientific, and technical literature vary in their orientation toward the speed and extent of environmental change in the first half of the 21st century:
  - **Positive:** One view is that environmental conditions have been improving since the 1950s, as societies have become richer and technologically better able to deal with environmental

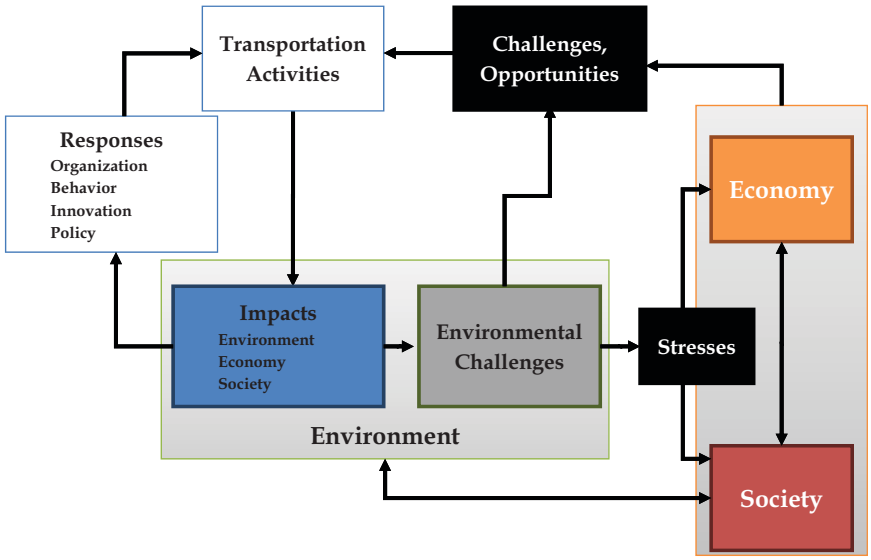


Figure A-9. Relationship between transportation systems and the environment.

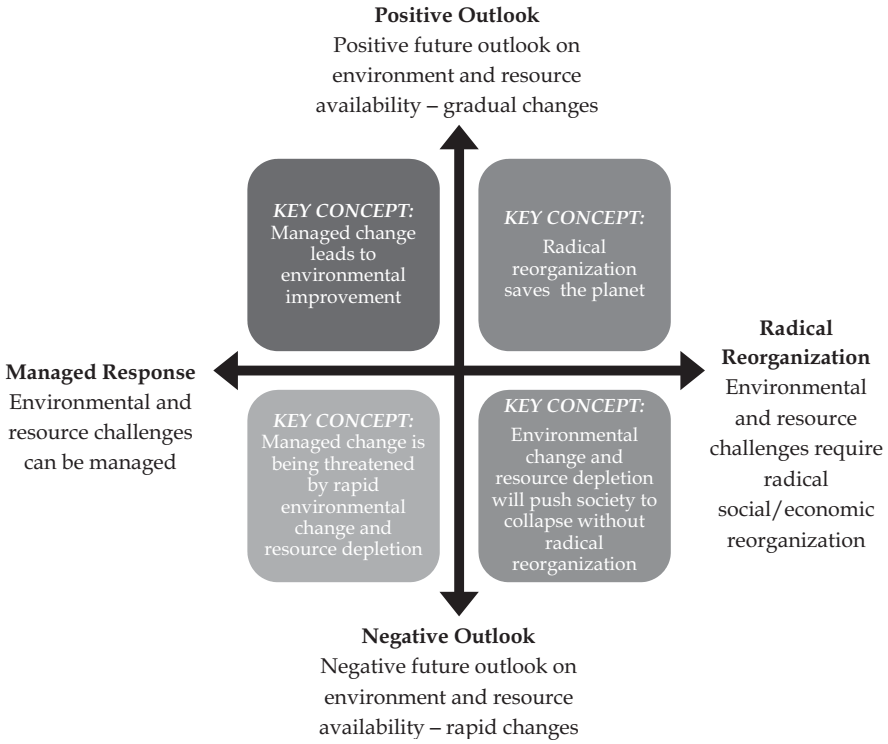


Figure A-10. The environmental management quadrant: dimensions of environmental and resource change in futurist environmental/ resource and scientific and technical literature.

problems. Based on this view, and what proponents claim to be scientific consensus, it is argued that environmental and resource change will be relatively gradual in the first half of the 21st century and that a variety of market, technological, and regulatory responses will be able to manage these changes successfully.
  - **Negative:** A more radical view is that the current scientific consensus underestimates the speed and magnitude of change and that increasing resource shortages (e.g., water, oil, rare metals, and soil depletion), rapid environmental change, and a worsening environment in most areas will characterize the first half of the 21st century [for an example of this view, see Hansen (2010); McKibben (2010)].
- **Management/Planning:** A second dimension addresses the degree to which current institutions (i.e., political, economic, and social) are able to adapt and address these changes:
  - **Managed response:** One view holds that the current political, economic, and social system will be able to manage environmental and resource availability changes. Some analysts believe that climate change will be dramatic and more rapid than is currently foreseen and that the current system will be sorely tested; however, these analysts believe that the current institutional and economic system will be able to meet the challenges posed by the environment and resource usage in the next few decades. Typically, these analysts envision that an emerging environmental or resource crisis will lead to a technological or socio-cultural response that will generate a new consensus and new tools within current political and social institutions to deal with environmental problems over the second half of the 21st century, as change eventually overwhelms the current system [for an overview of these challenges, see Nature Editorial Staff (2009)].
  - **Radical reorganization:** A more radical view holds that only a radical reorganization of society and the economy around sustainability and environmental protection can stave off collapse [for an example of this view, see Martenson (2011), Jackson (2009)]. In some cases, this change occurs only after environmental and resource crises have demonstrated that the current system can no longer manage global change; in other cases, change occurs before the crisis and heads off the crisis (Kahn, 2010).

Using this framework, the research team developed a series of alternative possible outcomes for use in developing scenarios. Table A-6 shows these outcomes.

Transportation Technology

This driver involves potential technical developments in vehicle-based communications, vehicle materials, power systems, and infrastructure.

Significance

The development and adoption of transportation technologies will affect travelers' mobility options and the fuels needed to power these options.

Trends

Transportation technologies of the future likely will vary substantially from what is available currently. The team expects to see changes in communications and information technologies that affect vehicles and how they interact with infrastructure, changes in materials that affect vehicles and infrastructure, potential changes in both fuels and in engines that use a variety of fuels, and changes in the infrastructure itself.

Table A-6. Potential future outcomes of environmental trends, resource use, and societal response.

Future of the Environment and Resource Use	Societal Response	
	Managed Response	Radical Reorganization
Positive Vision of Environmental and Resource Use Trends	Under this vision, environmental change is slow and manageable. Thus, while there will be significant stress from growing population and development, optimistic analysis of future environmental trends notes that most of these challenges are most likely to occur in developing countries. While these are serious challenges, optimistic analysts stress that efforts are already under way to address them and that, as these societies develop, they will follow a pattern similar to that of currently developed societies. Analysts who support this vision argue that while environmental challenges will continue to exist, the United States and other nations will be able to manage these challenges through a mixture of regulation and technological fixes.	Under this vision, environmental challenges can be addressed only by radical social, economic, and institutional changes to create a more sustainable society. Typically, these analysts assume that a combination of technological (i.e., green technology) and social/cultural change will lead to a radical reorganization of society under sustainable principles. Analysts who support this vision frequently present a vision of far-reaching decentralization combined with urban centralization and a radical reorganization of the economy and technology toward environmentally benign goals.
Negative Vision of Environmental and Resource Use Trends	Under this vision, environmental change is rapid and threatens to overwhelm the ability of the current system to manage change. Challenges include stratospheric ozone layer depletion; uncontrolled land use changes; atmospheric aerosol pollution; chemical contamination of air, water, and soil by long-lasting chemical compounds; water shortages; disruption of the phosphorus and nitrogen cycles; loss of biodiversity; and climate change. Analysts who support this vision frequently also claim that environmental degradation will be combined with serious resource depletion (e.g., peak oil, water shortages) that will require substantial technology and regulatory changes for an effective response.	Under this vision, environmental change is rapid and overwhelms the current system to manage change. In response, there is a partial collapse of the global system, leading to an increase in sub-national and international conflicts. In the United States, there are major environmental disasters (e.g., rapid, dramatic sea-level rise, prolonged droughts in the Southwest and Midwest) and limited social or economic collapse in some areas (e.g., region-wide emergencies caused by repeated hits within a single season of major hurricanes or superstorms in vulnerable locations). Typically, these visions also combine a view of dramatic environmental change with rapid resource depletion. Ultimately, these challenges can be addressed only via a radical reorganization of global society. In the absence of this reorganization, U.S. society may face a major collapse in the second part of the 21st century.

Information and communications technologies may affect how drivers and passengers interact with vehicles and how vehicles interact with each other and the infrastructure itself. Drivers are already familiar with in-vehicle systems such as OnStar and Sync, which provide drivers with information about their vehicles and with access to vehicle diagnostics and entertainment systems. Many vehicle technologies increase safety by alerting drivers to local obstacles. The U.S. DOT is performing research related to connected vehicle systems that will allow vehicles to autonomously communicate with each other and with the infrastructure. Advances

in communication with the infrastructure (e.g., current electronic toll tags) could allow for toll payments and roadway user fees, in addition to obtaining data for traffic management systems.

Other TRB reports relevant to this driver

This section provides an overview of transportation technology trends. *NCHRP Report 750, Volume 3: Expediting Future Technologies for Enhancing Transportation System Performance* provides a detailed discussion of transportation technology. At the time of this writing, the scenarios developed as part of the research project that led to *NCHRP Report 750, Volume 3*, were not available to the research team. Note: The discussion of this driver is not intended to be a comprehensive discussion of the factors affecting transportation technology. Rather, it is intended to identify the major trends and issues that could be relevant to surface transportation technology over the next 30 to 40 years and the factors that may affect adoption of the technology.

There is the potential for change in both vehicle and infrastructure materials. Vehicles may be made out of lightweight materials that provide both energy and safety benefits. There are already many different transportation vehicles that use a variety of transportation fuels. Different fuels (e.g., diesel, gas, electric, hybrid, E85, biofuel, fuel cell) require different types of engines. Current engines are likely to become more efficient, leading to more power with less fuel.

The research suggests that pavements and other infrastructure facilities may be eventually made out of longer-lasting and potentially recyclable materials that will better withstand environmental and weather impacts. Some pavements will allow for better drainage, which should reduce the detrimental effects on ecosystems.

Other advances could make the infrastructure "smarter"; transportation systems of the future may have automated guideways within cities and between cities. For example, there may be personal rapid transit vehicles on fixed guideways within cities that allow users to punch in destinations, analogous to global positioning system (GPS) devices in current vehicles. Eventually, the United States may eventually have automated highways that take control of vehicles to get travelers to the next cities.

Technology over the next 40 years likely will vary according to both research and development (R&D) investment and technology adoption rates. Both technology development and technology adoption will need to occur before transportation technology has a large impact on the system:

- **Technology development:** Many of the technologies envisioned today can be developed for the right price. Development in this case refers to both the feasibility and possibility of developing a technology that can be implemented and the development of ways to manufacture the technology so that the price is attractive to users.
- **Technology adoption:** Technology adoption occurs for a variety of reasons. In general, the technology must do something different and must be at a price that is reasonable. There may be other reasons to adopt technology, however, such as government mandates or environmental pressures. As described above, some technologies require public infrastructure to be used fully. In early adoption, only some locations will have available the infrastructure required by that technology. The research team also expects that most technologies will exhibit economies of scale; that is, as they become more widely adopted, they will be produced more cheaply. Figure A-11 provides an S-curve of technology adoption.

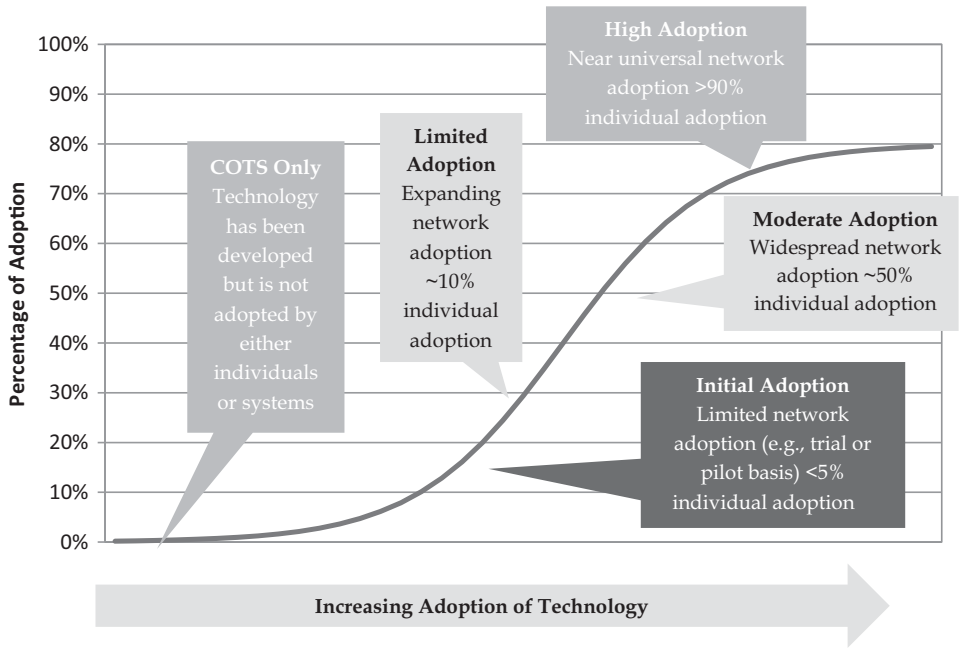


Figure A-11. Technology adoption curve.

Using this framework, the research team developed a series of alternative possible outcomes to be used to develop scenarios. Table A-7 shows these outcomes.

Land Use

Land use is the use and modification of land to support people's activities.

Significance

In the past, geographical boundaries (e.g., rivers, mountains) and major transportation facilities helped dictate where people lived, worked, and obtained goods and services. Currently, land

Table A-7. Potential outcomes related to transportation technology.

Potential Outcome	Vehicles	Infrastructure
Slow development, slow adoption	Only limited adoption of new technologies. Cost of the new technology may be prohibitive to the average user.	Only limited demonstrations of new technologies. Reliance on the private sector.
Medium development, medium adoption	Cost of new technologies may be large for the average person, resulting in uncertain benefits from limited adoption rates. Difficult chicken-and-egg problem between speed of development and adoption versus availability of public support to maximize use of the technology.	Without fast adoption, new types of guideways (for personal rapid transit or high-speed rail) will be limited to only a few locations.
Fast development, fast adoption	Costs reduced by economies of scale and network effects, which increase adoption rates at accelerating rates. Government mandates or incentives may speed adoption.	New types of vehicles require new guideways. Supported transportation facilities may change. Economies of scale or the recognition of potential network effects and positive spillovers may facilitate public funding for these changes.

use zoning and urban planning drive the uses of different tracts of land. If political situations change as expected across scenarios, the ability and role of government authorities to organize land use may differ between the future scenarios.

Trends

Land use is often closely tied to the sustainability of today's current transportation systems. Building or widening a road provides more capacity in the short term, which results in access to more housing, work locations, or goods and services, resulting in a Catch-22 of additional vehicles that fill this increased capacity, thus increasing congestion once again. In many places in the United States, it is difficult to obtain land to build additional road/rail capacity, which in turn makes building additional capacity a cost-prohibitive and socially disruptive approach to ease congestion. It is relatively easy to agree that this cycle of building capacity, thereby inducing demand, and then responding to the increased capacity, is not sustainable.

In response to the need and desire for work and housing to be co-located, there is a movement in the United States for Smart Growth sites or mixed-land-use areas where housing, work facilities, and retail stores are located close to each other. Such areas are intended to improve quality of life by reducing commute times and the time required to acquire goods and services, such as groceries and dry cleaning. Their intent is to attract people who want resources close by. Some experts predict that these mixed-land-use developments will continue to become more popular in the United States, as people seek alternatives to suburban sprawl and the long commutes to work locations.

As described previously, some urban planning efforts in the United States designate zones and specific land uses for specific geographical areas. Such zoning practices have been used to keep incompatible land uses separated (such as separating areas of heavy industry from housing). They also have been used to preserve the character of neighborhoods or areas. For example, a housing development built under specific zoning requirements cannot include retail operations, such as a grocery store. Increasing the separation of land uses may no longer be ideal, and under some future circumstances, preserving zones and preventing mixed land uses may not be practical or desired.

In extreme cases, people in the future may live in high-density complexes that provide housing, work options, goods, and services. High-density housing, such as the U.S. housing projects of the 1970s and today's Singaporean apartments, allow for economies of scale in building materials, access to resources, and utilization of resources, such as electricity and sewage systems, for land uses that in the past, would have been separated by legal requirements.

As in the previous discussions of drivers, note that land use practices of the future will be managed or unmanaged:

- **Managed:** Like today, managed land use includes zones that separate activities, such as housing and commercial space, and move toward mixed-use facilities.
- **Unmanaged:** Some areas do not have zoning regulations that prescribe land uses. Devolution of government authority may lead to unmanaged land use.

Table A-8 shows potential outcomes arrayed with the different land use options.

Future Transportation System Funding, Operation, and Control

This driver considers how future transportation systems will be organized and the role of the different players in the process.

Table A-8. Potential outcomes related to land use.

Potential Land Use Outcome	Managed	Unmanaged
Suburban sprawl; low-density land use	Land use zoning continues to separate agricultural, residential, commercial, and industrial land functions.	Without management, landowners use their land as they please. This may result in random placement of commercial opportunities or multifamily housing.
Medium-density land use; some mixed-density areas	Zoning is relaxed, which allows some mixed-density (Smart Growth) areas to arise.	Residential and commercial development occurs near attractions (e.g., open space, transportation facilities). Development is largely market driven.
High-density land use with mixed-density urban centers	Lack of transportation resources (such as fuel for personal vehicles) or environmentally based decisions require mandates for high-density housing complexes. Ideally, these include commercial functions.	Without management, some commercial and residential facilities may become isolated from others. The market is not able to support transportation needs.

Significance

How transportation will be different in various scenarios must be considered so that expected changes can be accommodated. Changes likely will affect mobility, safety, and the systems' ability to be sustainable.

Trends

There is a large body of literature on future transportation patterns [for example, see Bingham (2001), Regional Plan Association (n.d.), World Energy Council (2007)]. The intent of this project is not to address these issues. Rather, this project focuses on understanding how these changes are likely to affect organizing principles for state and local transportation agencies. Having reviewed this literature, the research team identified three major factors related to state transportation agencies:

- **Funding:** How will the transportation system of the future be funded?
- **Roles of private- and public-sector actors:** What will be the mix of private and public responsibilities in the future transportation system?
- **Centralization and decentralization:** How will responsibilities be distributed among different levels of government and, in particular, what will be the role of the federal government?

Each of these factors is discussed in greater detail in the following sections:

Funding

A critical question for the future organizing principles of state transportation agencies is the source of funding available for transportation [see Committee for the Study of the Long-Term Viability of Fuel Taxes for Transportation Finance (2007)]. Funding transportation has always been a challenge for state transportation agencies. In fact, funding U.S. surface transportation has been characterized as being in a state of "perpetual crisis" since the 1850s, where revenues have never been sufficient to meet needs and there is constant pressure to identify new funding sources [see Seely (2008)]. At present, it is clear that the current national and state gas taxes are not sufficient for maintaining current U.S. infrastructure, let alone for expansion or for new

infrastructure (National Surface Transportation Infrastructure Financing Commission, 2009; National Surface Transportation Policy and Revenue Commission, 2007). According to the National Surface Transportation Policy and Revenue Commission and the National Surface Transportation Infrastructure Financing Commission, there is a gap between revenues from gas taxes and capital investment and roadway maintenance needs. Furthermore, vehicles are more gas efficient (a trend that is expected to continue, resulting in further decreases in revenue from that source). The federal gas tax has not changed since 1993, so with vehicle efficiencies increasing and buying power decreasing, less infrastructure can be built or maintained. Both commissions suggest that sources in addition to gas taxes, such as direct user-based fees (e.g., toll revenues, congestion charges, vehicle miles traveled fees), are needed to better fill the gap.

As resources devoted to transportation become more constrained (either through increased fuel costs or other crises or because a replacement funding mechanism is not identified), transportation agencies likely will have to make increasing tradeoffs in transportation. This leads to a number of questions, such as: Will they be able to maintain all roads and bridges or will they have to respond to traffic demands or roads and bridges in the worst condition? Will they be able to provide winter maintenance 24/7 or only during some time periods? Can structures be categorized deficient and their use restricted so that limited resources can go to other structures? Should an urban area maintain its freeways or invest more money into its arterials (Zhang and Xu, 2011).

While public and government agencies will be making difficult decisions about what to maintain, private entities may become increasingly involved in transportation systems. For example, private companies may identify roadways that they think they can maintain or enhance using private sources (like tolls) and then offer to operate the roadways at a profit (this is happening in several locations in the United States, including the Indiana Toll Road, Texas State Highway 121, and the Capital Beltway High Occupancy Toll Lanes in Northern Virginia). Local communities also may seek private funding to rebuild roadways or bridges that have been labeled deficient.

Roles of Private- and Public-Sector Actors

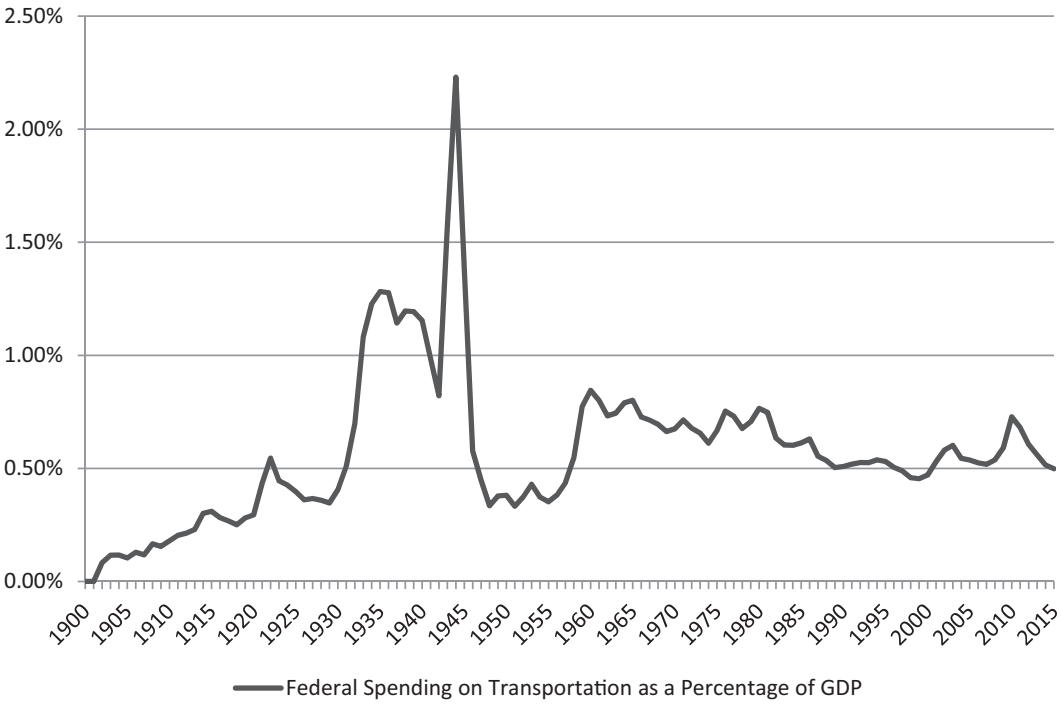
The degree of private ownership of infrastructure will vitally affect the future organizing principles for state transportation agencies. The public and private sectors have played different roles and have operated under a variety of different regulatory regimes in the U.S. transportation system. It is likely that there will be continuing change in the balance and responsibilities of the public and private sectors as different pressures and events continue to affect the development of the U.S. transportation system. In particular, difficulties in funding the extant public transportation may lead to greater pressures to share ownership and responsibilities for operations.

For example, private entities may become willing operators of routes that have a greater chance of covering operating costs. There are privately operated car-sharing companies already, such as FlexCar and ZipCar [see Carsharing.net (n.d.) for examples]. More private companies may enter the markets to provide services, including mechanisms for ride sharing for commuters (e.g., the SLUG commuting system in Northern Virginia), people going on trips, older people needing rides to doctor's offices, and so on. Privatized transit services may increase if current public transportation agencies are unable to sustain their services or if they cut some of their services in response to changes in public transportation funding or national crises.

Centralization and Decentralization

The degree of centralization and decentralization in the control of the transportation system will be vitally important to the future organizing principles of state transportation agencies. U.S. transportation policy in the 20th century was a story of increasing federal involvement in transportation (Dilger, 2003). Specifically, in the early 20th century, the federal government expanded its role into the transportation policy system gradually. Beginning as a provider of expertise and knowledge (i.e., the period of "engineers as problem solvers") in the early 20th century and gradually moving into a position of financing and building surface transportation systems in the Great Depression and the Interstate Era, the federal government became a major player and funder of the transportation system. Since the peak of its involvement in the 1940s, however, the federal role has declined (although there was federal involvement in urban transit in the 1960s and the Intermodal Surface Transportation Act era) (see Figure A-12).

In the future, the federal government will face conflicting pressures in terms of its involvement in transportation. On one hand, the pressure for greater sustainability, greater coordination, and maintaining equity between rich and poor regions of the country suggest that the federal government should become more involved in transportation. On the other hand, the growing demands on the federal government from numerous competing national priorities (e.g., supporting an aging population, dealing with climate change, and addressing deficit and debt issues) and a lack of resources to address these major challenges may mean that the federal government must withdraw from many areas and focus on key issues where it plays a vital, irreplaceable role.



Source: Bloomberggoverment.com

Figure A-12. Federal spending on transportation as a percentage of GDP, 1900 to 2015 (estimated).

In addition to uncertainty about the future of the federal role, there are similar uncertainties regarding the role of state governments. As with the federal government, state governments face several challenges, including, but not limited to, the following:

- Resource-demand mismatch (i.e., increasing demands on state governments, but a lack of resources to meet those demands, especially in states with statutory balanced-budget requirements)
- Increased requirements for regional planning, both within states for agencies such as Metropolitan Planning Organizations (MPOs) and among states (e.g., coordination within the Northeast Corridor)
- Need to develop new financing mechanisms based on user fees
- Growing requirements to integrate transportation planning into broader sustainability planning and decisionmaking

These challenges could lead to a number of responses. On one hand, state transportation agencies and state governments could reassert their role in the transportation system and become the dominant player, acting as a coordinator and manager of the system. On the other hand, state transportation agencies could cede some of the fiscal commitments associated with being heavily involved in transportation, giving some of their authority and responsibilities to sub-state authorities (e.g., MPOs) or supra-state authorities (e.g., megaregional planning authorities).

Taking these two variables together, the research team created a few potential alternatives of the extent of centralized and decentralized planning and management (see Figure A-13).

Taking all of these trends together, the research team created the following matrix which combines these options into a series of potential outcomes (see Table A-9).

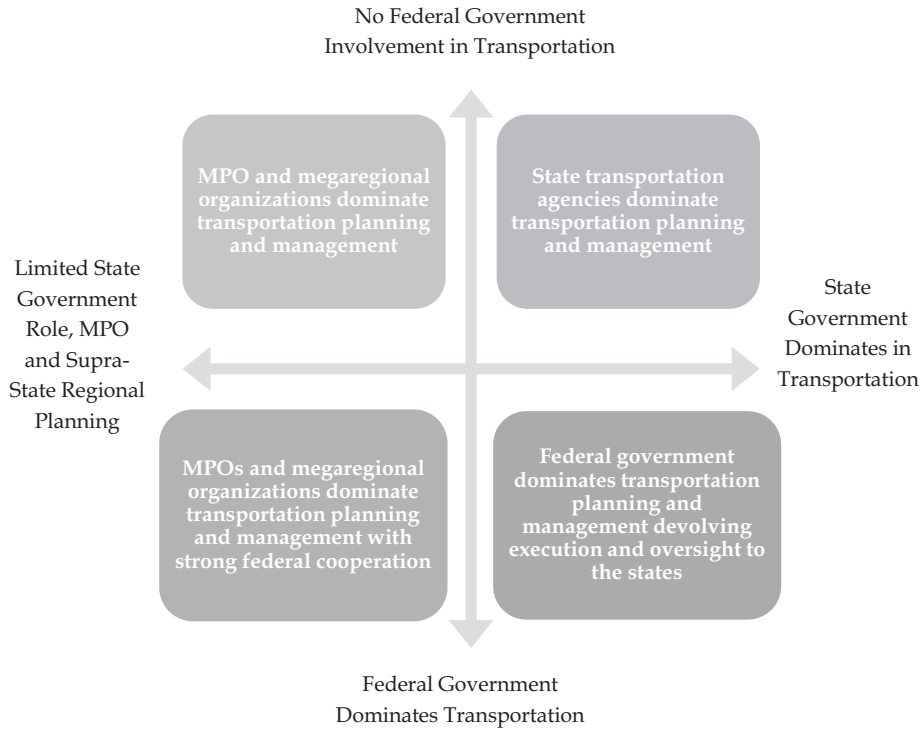


Figure A-13. Future federal, state, local, and regional transportation planning and management roles.

Table A-9. Potential outcomes related to future transportation impacts.

	MPO and megaregional organizations dominate transportation planning and management		MPOs and megaregional organizations dominate transportation planning and management with strong federal cooperation		State transportation agencies dominate transportation planning and management		Federal government dominates transportation planning and management devolving execution and oversight to the states	
Funding Mechanism	**Limited Private Role**	**Significant Private Role**	**Limited Private Role**	**Significant Private Role**	**Limited Private Role**	**Significant Private Role**	**Limited Private Role**	**Significant Private Role**
Limited New Funding Mechanisms and Sources	Some roadways and bridges will fall into disrepair. Limited public transportation options. Investment, management, and control focus on megaregions and MPOs. Transportation systems outside megaregions and metropolitan areas decline.	Without new funding mechanisms, only high-demand toll roads will be operated by private entities. Investment, management, and control focus on megaregions and MPOs. Transportation systems outside megaregions and metropolitan areas decline.	Some roadways and bridges will fall into disrepair. Limited public transportation options. Investment, management, and control focus on megaregions and MPOs, with federal government focusing on interregional transport.	Without new funding mechanisms, only high-demand toll roads will be privatized. Investment, management, and control focus on megaregions and MPOs, with the federal government focusing on interregional transport in cooperation with privatized transportation organizations.	Some roadways and bridges will fall into disrepair. Limited public transportation options. State transportation agencies oversee the planning and management of transportation systems.	Without new funding mechanisms, only high-demand toll roads will be privatized. State transportation agencies oversee the planning and management of transportation systems, with most systems jointly managed by state and private organizations.	Some roadways and bridges will fall into disrepair. Limited public transportation options. Management and planning systems resemble the 1950s and 1960s.	Without new funding mechanisms, only high-demand toll roads will be privately operated. Management and planning systems resemble the 1950s and 1960s, with substantial private roles.
Some New Funding Mechanisms and Sources	Agencies will have to make difficult tradeoffs on what to provide and maintain. Investment, management, and control focus on megaregions and MPOs. Transportation systems outside megaregions and metropolitan areas decline.	Roads and transit may be operated and/or owned privately. Private ownership may lead to great discrepancies in available transportation—richer areas will have better facilities and services. Investment, management, and control focus on megaregions and MPOs. Transportation systems outside megaregions and metropolitan areas decline or are transferred to private sector control.	Agencies will have to make difficult tradeoffs on what to provide and maintain. Investment, management, and control focus on megaregions and MPOs, with the federal government focusing on interregional transport.	Roads and transit may be operated and/or owned privately. Private ownership may lead to great discrepancies in available transportation—richer areas will have better facilities and services. Investment, management, and control focus on megaregions and MPOs, with the federal government focusing on interregional transport in cooperation with privatized transportation organizations.	Agencies will have to make difficult tradeoffs on what to provide and maintain. State transportation agencies oversee the planning and management of transportation systems.	Roads and transit may be operated and/or owned privately. Private ownership may lead to great discrepancies in available transportation—richer areas will have better facilities and services. State transportation agencies oversee the planning and management of transportation systems, with most systems jointly managed by state and private organizations.	Agencies will have to make difficult tradeoffs on what to provide and maintain. Management and planning systems resemble the 1950s and 1960s, but with greater user fees.	Roads and transit may be operated and/or owned privately. Private ownership may lead to great discrepancies in available transportation—richer areas will have better facilities and services. Management and planning systems resemble the 1950s and 1960s, with substantial private roles.

(continued on next page)

Table A-9. (Continued).

	MPO and megaregional organizations dominate transportation planning and management		MPOs and megaregional organizations dominate transportation planning and management with strong federal cooperation		State transportation agencies dominate transportation planning and management		Federal government dominates transportation planning and management devolving execution and oversight to the states	
Funding Mechanism	**Limited Private Role**	**Significant Private Role**	**Limited Private Role**	**Significant Private Role**	**Limited Private Role**	**Significant Private Role**	**Limited Private Role**	**Significant Private Role**
Many New Funding Mechanisms and Sources	Improved transportation (greater transit frequency; more access and mobility). Investment, management, and control focus on megaregions and MPOs. Transportation systems outside megaregions and metropolitan areas decline.	Improved transportation (greater transit frequency; more access and mobility). Investment, management, and control focus on megaregions and MPOs. Transportation systems outside megaregions and metropolitan areas decline or are transferred to private sector control.	Improved transportation (greater transit frequency; more access and mobility). Investment, management, and control focus on megaregions and MPOs, with the federal government focusing on interregional transport.	Improved transportation (greater transit frequency; more access and mobility). Investment, management, and control focus on megaregions and MPOs, with the federal government focusing on interregional transport in cooperation with private transportation organizations.	Improved transportation (greater transit frequency; more access and mobility). State transportation agencies oversee the planning and management of transportation systems.	Improved transportation (greater transit frequency; more access and mobility). State transportation agencies oversee the planning and management of transportation systems, with most systems jointly managed by state and private organizations.	Improved transportation (greater transit frequency; more access and mobility). Management and planning systems resemble the 1950s and 1960s, but with greater user fees.	Improved transportation (greater transit frequency; more access and mobility). Management and planning systems resemble the 1950s and 1960s, with substantial private roles.

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APPENDIX B

Federal, State, and Local Transportation Spending

1961 to 2015 [Estimated billions of dollars (nominal) as a percentage of GDP]

Year	US GDP	Federal Spending			State Spending			Local Spending			Federal Transfers to State and Local Governments		Total Federal, State, Local Spending		
	$ billion	$ billion	Notes	% of GDP	$ billion	Notes	% of GDP	$ billion	Notes	% of GDP	$ billion	Notes	$ billion	Notes	% of GDP
1960	526.4	4.45	a	0.85%	6.15	a	1.17%	4.6	a	0.87%	-2.91	a	12.29	a	2.33%
1961	544.8	4.36	a	0.80%	6.33	a	1.16%	4.98	a	0.91%	-2.59	a	13.08	a	2.40%
1962	585.7	4.29	a	0.73%	6.73	a	1.15%	5.06	a	0.86%	-2.75	a	13.33	a	2.28%
1963	617.8	4.6	a	0.74%	7.52	a	1.22%	5.09	a	0.82%	-2.98	a	14.23	a	2.30%
1964	663.6	5.24	a	0.79%	7.94	a	1.20%	5.32	a	0.80%	-3.63	a	14.87	a	2.24%
1965	719.1	5.76	a	0.80%	8.31	a	1.16%	5.73	a	0.80%	-4	a	15.8	a	2.20%
1966	787.7	5.73	a	0.73%	8.73	a	1.11%	5.9	a	0.75%	-3.95	a	16.41	a	2.08%
1967	832.4	5.94	a	0.71%	9.54	a	1.15%	6.47	a	0.78%	-4.06	a	17.89	a	2.15%
1968	909.8	6.32	a	0.69%	9.95	a	1.09%	7.01	a	0.77%	-4.29	a	18.99	a	2.09%
1969	984.4	6.53	a	0.66%	10.59	a	1.08%	7.77	a	0.79%	-4.35	a	20.54	a	2.09%
1970	1038.3	7.01	a	0.68%	11.25	a	1.08%	8.35	a	0.80%	-4.61	a	22	a	2.12%
1971	1126.8	8.05	a	0.71%	12.27	i	1.09%	9.4	i	0.83%	-4.99	a	24.73	i	2.19%
1972	1237.9	8.39	a	0.68%	12.84	i	1.04%	10.05	i	0.81%	-4.92	a	26.36	i	2.13%
1973	1382.3	9.07	a	0.66%	12.79	i	0.93%	10.55	i	0.76%	-4.71	a	27.7	i	2.00%
1974	1499.5	9.17	a	0.61%	13.63	i	0.91%	11.51	i	0.77%	-4.55	a	29.76	i	1.98%
1975	1637.7	10.92	a	0.67%	15.29	i	0.93%	13.44	i	0.82%	-5.32	a	34.33	i	2.10%
1976	1824.6	13.74	a	0.75%	16.2	i	0.89%	14.58	i	0.80%	-6.34	a	38.18	i	2.09%
1977	2030.1	14.83	a	0.73%	16	i	0.79%	15.32	i	0.75%	-6.48	a	39.67	i	1.95%
1978	2293.8	15.52	a	0.68%	16.9	i	0.74%	16.19	i	0.71%	-6.4	a	42.21	i	1.84%
1979	2562.2	18.08	a	0.71%	19.3	i	0.75%	18.8	i	0.73%	-7.15	a	49.03	i	1.91%
1980	2788.1	21.33	a	0.77%	22.35	i	0.80%	22.11	i	0.79%	-8.98	a	56.81	i	2.04%
1981	3126.8	23.38	a	0.75%	23.55	i	0.75%	24.5	i	0.78%	-9.51	a	61.92	i	1.98%
1982	3253.2	20.62	a	0.63%	23.88	i	0.73%	25.98	i	0.80%	-8.44	a	62.04	i	1.91%
1983	3534.6	21.33	a	0.60%	25.39	i	0.72%	28.16	i	0.80%	-9.14	a	65.74	i	1.86%
1984	3930.9	23.67	a	0.60%	27.2	i	0.69%	30.42	i	0.77%	-10.61	a	70.68	i	1.80%
1985	4217.5	25.84	a	0.61%	30.56	a	0.72%	33.78	a	0.80%	-12.99	a	77.19	a	1.83%
1986	4460.1	28.12	a	0.63%	33.83	a	0.76%	36.23	a	0.81%	-14.14	a	84.04	a	1.88%
1987	4736.4	26.22	a	0.55%	35.42	a	0.75%	39.11	a	0.83%	-13.24	a	87.51	a	1.85%
1988	5100.4	27.27	a	0.53%	37.91	a	0.74%	41.29	a	0.81%	-13.82	a	92.65	a	1.82%
1989	5482.1	27.61	a	0.50%	39.62	i	0.72%	44.12	i	0.80%	-14.1	i	97.25	i	1.77%
1990	5800.5	29.49	a	0.51%	41.34	a	0.71%	47.01	a	0.81%	-14.37	a	103.47	a	1.78%
1991	5992.1	31.1	a	0.52%	44.24	a	0.74%	50.38	a	0.84%	-14.56	a	111.16	a	1.86%
1992	6342.3	33.33	a	0.53%	47.36	a	0.75%	54.06	a	0.85%	-19	a	115.75	a	1.83%
1993	6667.4	35	a	0.52%	48.84	a	0.73%	54.12	a	0.81%	-20.74	a	117.22	a	1.76%

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Year	US GDP	Federal Spending			State Spending			Local Spending			Federal Transfers to State and Local Governments		Total Federal, State, Local Spending		
	$ billion	$ billion	Notes	% of GDP	$ billion	Notes	% of GDP	$ billion	Notes	% of GDP	$ billion	Notes	$ billion	Notes	% of GDP
1994	7085.2	38.07	a	0.54%	51.3	a	0.72%	59.69	a	0.84%	-23.41	a	125.65	a	1.77%
1995	7414.7	39.35	a	0.53%	54.69	a	0.74%	61.38	a	0.83%	-24.9	a	130.52	a	1.76%
1996	7838.5	39.57	a	0.50%	55.82	a	0.71%	63.01	a	0.80%	-24	a	134.4	a	1.71%
1997	8332.4	40.77	a	0.49%	57.26	a	0.69%	66.87	a	0.80%	-24.83	a	140.07	a	1.68%
1998	8793.5	40.34	a	0.46%	61.65	a	0.70%	69.95	a	0.80%	-25.05	a	146.89	a	1.67%
1999	9353.5	42.53	a	0.45%	66.49	a	0.71%	74.41	a	0.80%	-26.39	a	157.04	a	1.68%
2000	9951.5	46.85	a	0.47%	74.47	a	0.75%	79.39	a	0.80%	-29.52	a	171.19	a	1.72%
2001	10286	54.45	a	0.53%	77.91	a	0.76%	87.24	a	0.85%	-35.24	a	184.36	a	1.79%
2002	10642	61.83	a	0.58%	82.95	a	0.78%	92.66	a	0.87%	-39.33	a	198.11	a	1.86%
2003	11142	67.07	a	0.60%	90.51	a	0.81%	97.82	a	0.88%	-38.61	a	216.79	a	1.95%
2004	11868	64.63	a	0.54%	86.7	a	0.73%	104.76	a	0.88%	-38.97	a	217.12	a	1.83%
2005	12638	67.89	a	0.54%	90.86	a	0.72%	102.56	a	0.81%	-43.12	a	218.19	a	1.73%
2006	13399	70.24	a	0.52%	100.17	a	0.75%	107.44	a	0.80%	-45.07	a	232.78	a	1.74%
2007	14078	72.91	a	0.52%	104.47	a	0.74%	115.47	a	0.82%	-47.39	a	245.46	a	1.74%
2008	14441	77.62	a	0.54%	104.16	a	0.72%	126.5	a	0.88%	-48.72	a	259.56	a	1.80%
2009	14258	84.29	a	0.59%	107.72	g	0.76%	135.63	g	0.95%	-50.09	g	277.55	g	1.95%
2010	14624	106.46	b	0.73%	111.6	g	0.76%	145.53	g	1.00%	-51.51	g	312.08	g	2.13%
2011	15299	104.19	b	0.68%	115.81	g	0.76%	156.27	g	1.02%	-52.97	g	323.3	g	2.11%
2012	16203	98.19	b	0.61%	120.39	g	0.74%	167.94	g	1.04%	-54.47	g	332.05	g	2.05%
2013	17182	96.16	b	0.56%	125.37	g	0.73%	180.62	g	1.05%	-56.02	g	346.13	g	2.01%
2014	18193	93.65	b	0.51%	130.81	g	0.72%	194.42	g	1.07%	-57.61	g	361.27	g	1.99%
2015	19190	95.65	b	0.50%	136.73	g	0.71%	209.44	g	1.09%	-59.26	g	382.56	g	1.99%

Legend:
a - actual reported
i - interpolated between actual reported values
g - 'guesstimated' projection by usgovernmentspending.com
b - budgeted estimate in United States fy11 budget
Source: USGovernmentspending.com, 2011, Bloomberg Government

APPENDIX C

NEMS Energy Consumption Forecasts

	Percentage of quadrillion Btu (unless otherwise noted)				
Supply and Disposition	**2010**	**2020**	**2030**	**2040**	**2050**
MODERATE ECONOMIC GROWTH CASE					
Production					
Crude Oil and Lease Condensate	16%	16%	15%	14%	12%
Natural Gas Plant Liquids	3%	3%	3%	3%	2%
Dry Natural Gas	28%	25%	26%	26%	25%
Coal	29%	29%	28%	29%	33%
Nuclear Power	12%	11%	11%	10%	10%
Hydropower	4%	4%	3%	3%	3%
Biomass	5%	7%	9%	10%	9%
Other Renewable Energy	3%	4%	4%	4%	5%
Other	1%	1%	1%	1%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**
Imports					
Crude Oil	66%	64%	65%	64%	64%
Liquid Fuels	18%	19%	20%	21%	22%
Natural Gas	13%	14%	13%	10%	8%
Other Imports	3%	3%	3%	5%	7%
Total	**100%**	**100%**	**100%**	**100%**	**102%**
Exports					
Petroleum	55%	57%	59%	60%	60%
Natural Gas	17%	22%	28%	29%	31%
Coal	28%	20%	13%	11%	9%
Total	**100%**	**100%**	**100%**	**100%**	**100%**
Consumption					
Liquid Fuels	38%	37%	37%	36%	36%
Natural Gas	24%	22%	22%	22%	21%
Coal	21%	22%	22%	23%	26%
Nuclear Power	9%	9%	8%	8%	8%
Hydropower	3%	3%	3%	3%	2%
Biomass	3%	4%	5%	4%	3%
Other Renewable Energy	2%	3%	3%	3%	4%
Other	0%	0%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**101%**

(continued on next page)

	Percentage of quadrillion Btu (unless otherwise noted)				
Supply and Disposition	**2010**	**2020**	**2030**	**2040**	**2050**
LOW ECONOMIC GROWTH CASE					
Production					
Crude Oil and Lease Condensate	16%	16%	16%	16%	16%
Natural Gas Plant Liquids	3%	3%	3%	3%	2%
Dry Natural Gas	28%	25%	26%	26%	26%
Coal	29%	29%	28%	28%	27%
Nuclear Power	12%	12%	11%	11%	10%
Hydropower	4%	4%	4%	3%	3%
Biomass	5%	7%	8%	10%	12%
Other Renewable Energy	2%	3%	3%	3%	4%
Other	1%	1%	1%	1%	0%
Total	**100%**	**100%**	**100%**	**100%**	**101%**
Imports					
Crude Oil	66%	64%	65%	63%	61%
Liquid Fuels	18%	19%	19%	20%	22%
Natural Gas	13%	14%	12%	11%	10%
Other Imports	3%	3%	3%	5%	13%
Total	**100%**	**100%**	**100%**	**100%**	**105%**
Exports					
Petroleum	55%	57%	58%	57%	55%
Natural Gas	17%	23%	29%	33%	36%
Coal	28%	20%	13%	11%	9%
Total	**100%**	**100%**	**100%**	**100%**	**101%**
Consumption					
Liquid Fuels	38%	37%	37%	36%	34%
Natural Gas	24%	22%	22%	22%	22%
Coal	21%	22%	22%	23%	24%
Nuclear Power	9%	9%	9%	9%	8%
Hydropower	3%	3%	3%	3%	3%
Biomass	3%	4%	4%	5%	5%
Other Renewable Energy	2%	2%	2%	3%	3%
Other	0%	0%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**
HIGH ECONOMIC GROWTH CASE					
Production					
Crude Oil and Lease Condensate	16%	16%	15%	13%	11%
Natural Gas Plant Liquids	3%	3%	3%	2%	2%
Dry Natural Gas	28%	25%	26%	25%	24%
Coal	29%	29%	28%	28%	28%
Nuclear Power	12%	11%	10%	10%	11%
Hydropower	4%	4%	3%	3%	3%
Biomass	5%	7%	10%	13%	16%
Other Renewable Energy	3%	5%	5%	5%	5%
Other	1%	1%	1%	1%	1%
Total	**100%**	**100%**	**100%**	**100%**	**101%**

	Percentage of quadrillion Btu (unless otherwise noted)				
Supply and Disposition	**2010**	**2020**	**2030**	**2040**	**2050**
Imports					
Crude Oil	66%	65%	64%	65%	67%
Liquid Fuels	18%	19%	20%	21%	21%
Natural Gas	13%	13%	12%	10%	8%
Other Imports	3%	3%	4%	4%	5%
Total	**100%**	**100%**	**100%**	**100%**	**101%**
Exports					
Petroleum	55%	58%	62%	64%	69%
Natural Gas	17%	21%	26%	25%	24%
Coal	28%	20%	12%	11%	9%
Total	**100%**	**100%**	**100%**	**100%**	**101%**
Consumption					
Liquid Fuels	38%	38%	37%	37%	36%
Natural Gas	24%	22%	22%	21%	20%
Coal	21%	22%	21%	21%	22%
Nuclear Power	9%	8%	8%	8%	9%
Hydropower	3%	3%	3%	2%	2%
Biomass	3%	4%	5%	6%	8%
Other Renewable Energy	2%	4%	4%	4%	4%
Other	0%	0%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**101%**

APPENDIX D

Research and Data Collection

This appendix describes the data collection and analysis approach the research team took to characterize the current literature and stakeholder perceptions on sustainability and transportation agencies. First, the team conducted a detailed literature review and state-of-the-practice scan on how transportation agencies in the United States and other countries deal with sustainability. The team also reviewed the literature on how the federal government (including specific federal government agencies) and the private sector deal with sustainability. Second, the team interviewed 54 practitioners to obtain their views on how transportation agencies are dealing with sustainability issues and the challenges of implementing sustainable policies. Appendix E lists the interviewees. The team synthesized and integrated this information while identifying key insights, findings, and issues.

D.1 Findings

D.1.1 State Governments and State DOTs

Understanding of Sustainability and the Role of Sustainability in State DOTs

Awareness and understanding of sustainability have been increasing at all levels of government in the United States. For example, according to the FHWA, a little more than half of state DOTs include sustainability principles in their mission statements, as shown in Table D-1. Two use the word "sustainable," while the rest mention the need to balance the economy, environment, and quality of life.[D1] However, no state has a legislatively authorized sustainable transportation program.

[D1] Data was collected from 2010 to 2011.

Table D-1. State DOTs with sustainability mission statements.

DOT	Mission Statement
Alabama	To provide a safe, efficient, environmentally sound intermodal transportation system for all users, especially the taxpayers of Alabama. To also facilitate economic and social development and prosperity through the efficient movement of people and goods and to facilitate intermodal connections within Alabama. Alabama DOT must also demand excellence in transportation and be involved in promoting adequate funding to promote and maintain Alabama's transportation infrastructure.
Arkansas	It is our mission to provide and maintain a safe, effective, and environmentally sound transportation system for the state.
Connecticut	To provide a safe and efficient intermodal transportation network that improves the quality of life and promotes economic vitality for the state and the region.
Delaware	To provide a safe, efficient, and environmentally sensitive transportation network that offers a variety of convenient and cost-effective choices for the movement of people and goods.
Florida	To provide a safe transportation system that ensures the mobility of people and goods, enhances economic prosperity, and preserves the quality of our environment and communities.
Georgia	To provide a safe, seamless, and sustainable transportation system that supports Georgia's economy and is sensitive to its citizens and environment.
Hawaii	To provide a safe, efficient, accessible, and intermodal transportation system that ensures the mobility of people and goods, and enhances and/or preserves economic prosperity and the quality of life.
Iowa	Advocates and delivers transportation services that support the economic, environmental, and social vitality of Iowa.
Illinois	To provide safe, cost-effective transportation for Illinois in ways that enhance quality of life, promote economic prosperity, and demonstrate respect for our environment.
Indiana	Indiana DOT will plan, build, maintain, and operate a superior transportation system enhancing safety, mobility, and economic growth.
Kentucky	To provide a safe, efficient, environmentally sound, and fiscally responsible transportation system that delivers economic opportunity and enhances the quality of life in Kentucky.
Louisiana	To deliver transportation and public works systems that enhance quality of life and facilitate economic growth and recovery.
Maine	To responsibly provide a safe, efficient, and reliable transportation system that supports economic opportunity and quality of life.
Maryland	To efficiently provide mobility for our customers through a safe, well-maintained, and attractive highway system that enhances Maryland's communities, economy, and environment.
Michigan	To provide the highest quality integrated transportation services for economic benefit and improved quality of life.
Mississippi	To provide a safe intermodal transportation network that is planned, designed, constructed, and maintained in an effective, cost-efficient, and environmentally sensitive manner.
Montana	To serve the public by providing a transportation system and services that emphasize quality, safety, cost effectiveness, economic vitality, and sensitivity to the environment.
Nebraska	We provide and maintain, in cooperation with public and private organizations, a safe, efficient, affordable, environmentally compatible and coordinated statewide transportation system for the movement of people and goods.
New Hampshire	Transportation excellence in New Hampshire is fundamental to the state's sustainable economic development and land use, enhancing the environment and preserving the unique character and quality of life.
New Mexico	The primary responsibility of the agency is to plan, build, and maintain a quality statewide transportation network that will serve the social and economic interests of our citizens in a productive, cost-effective, innovative manner.
New York	It is the mission of the New York State DOT to ensure our customers—those who live, work and travel in New York State—have a safe, efficient, balanced, and environmentally sound transportation system.

Table D-1. (Continued).

DOT	Mission Statement
North Carolina	Connecting people and places in North Carolina—safely and efficiently, with accountability and environmental sensitivity.
Ohio	Moving Ohio into a Prosperous New World. Its meaning encompasses the multimodal, safe, efficient and reliable character identified in our last business plan mission statement. At the same time, it incorporates the realization that safety, economic development, green, innovative and accessible characteristics are additional drivers needed to achieve the prosperity that will assure Ohio's future competitiveness.
Oregon	To provide a safe, efficient transportation system that supports economic opportunity and livable communities for Oregonians.
Rhode Island	To maintain and provide a safe, efficient, and environmentally, aesthetically and culturally sensitive intermodal transportation network that offers a variety of convenient, cost-effective mobility opportunities for people and the movement of goods supporting economic development and improved quality of life.
South Dakota	We provide a quality transportation system to satisfy diverse mobility needs in a cost-effective manner, while retaining concern for safety and the environment.
Tennessee	To plan, implement, maintain, and manage an integrated transportation system for the movement of people and products, with emphasis on quality, safety, efficiency, and the environment.
Vermont	To provide for the movement of people and commerce in a safe, reliable, cost-effective, and environmentally responsible manner.
Virginia	To plan, deliver, operate, and maintain a transportation system that is safe, enables easy movement of people and goods, enhances the economy, and improves our quality of life.
West Virginia	To create and maintain for the people of West Virginia, the United States, and the world, a multimodal and intermodal transportation system that supports the safe, effective, and efficient movement of people, information, and goods that enhances the opportunity for people and communities to enjoy environmentally sensitive and economically sound development.

Source: Adapted from stakeholder interviews and research (Georgia Tech Research Corporation, 2011).

To date, very few states have an active sustainability plan or program. As of 2010, five state DOTs had a formal sustainability plan or program, as shown in Table D-2.

The data suggests that at the state level there is a growing adoption of sustainability terminology but limited implementation of TBL programs. The practitioner interviews support this observation. For example, many interviewees supported the general principles of sustainability, but some were reluctant to use the term as they felt the term to be polarizing and controversial, especially in the current climate in which resources are stretched thin and state governments are focusing on economic growth and job creation. Furthermore, the ideology of free-market economics and limited government that often infuses public discourse today would make the concept of government-enforced sustainability—deemed by some as government control of economic activity and freedom of choice—a difficult sell to state decisionmakers and the public. In addition, the conceptual complexity of the term and the challenge of developing consensus around an actionable definition hinder support for the concept. Many interviewees suggested that rather than emphasize the TBL, it is better to sell sustainability as "stewardship," which embodies responsible planning for and management of resources over an intergenerational period (e.g., "we must pass the world on to our children").

Another insight was that sustainability was frequently interpreted as support for green or environmental programs. Data from the FHWA's recent survey of state sustainability programs seem to support this insight. Table D-3 shows some examples of these programs. These initiatives encompass a wide variety of issues, including purchasing a more energy-efficient vehicle fleet to developing GHG emissions budgets and climate action plans.

Table D-2. State sustainability transportation plans.

DOT	Description
District of Columbia	The District of Columbia DOT developed a sustainability plan that reflects the TBL. The plan identifies eight priority areas for sustainability and establishes goals, actions, measures, and targets for each.
California	Pilot project with Environmental Protection Agency (EPA) to create a sustainability assessment framework for transportation policy, planning, and programming; currently being tested for corridor analyses, but will be used to assess regional and state efforts, as well.
Massachusetts	Statewide sustainable development principles adopted to guide policies, programs, and infrastructure investment decisions; partnering to coordinate transportation service planning and delivery.
New York	Sustainability is pursued through a statewide program (Smart Planning Program) integrating land use and transportation planning, including the provision of training, educational materials, and hands-on planning assistance. In addition, the state DOT is implementing the Green Leadership in Transportation Environmental Sustainability (GreenLITES), a transportation environmental sustainability rating program.
Oregon	Three-volume plan that will outline goals, actions, and performance measures for internal actions and external system management to achieve a sustainable transportation system*: Volume 1 (defining sustainability) released in January 2009, Volume 2 (internal operations) released in Fall 2010, and Volume 3 (managing statewide transportation network) under review.
Pennsylvania	Partnering with other agencies, states, and local communities to make financially, environmentally, and socially sustainable decisions; includes a public education campaign and a handbook co-authored by New Jersey DOT.
Washington	Annual plan update and progress report on sustainability targets and emerging issues.

* Includes integration of Least-Cost Planning as a component of the strategy.

Source: Adapted from stakeholder interviews and research (Georgia Tech Research Corporation, 2011).

Table D-3. Sample "green" or "environmental" programs.

DOT	Description
California	Active climate change mitigation and adaptation measures in response to state legislation; includes GHG reduction strategies, sea-level rise assessment, and habitat-connectivity study.
Delaware and Tennessee	Statewide geographic information system (GIS) data used to identify environmental issues during the planning process; requires GIS data from multiple state, regional, and local agencies.
Florida	Process to anticipate environmental problems early on through partnership with resource agencies, public involvement, and GIS-based environmental assessment.
Illinois	Initiatives to improve agency's internal sustainability (energy efficiency, emissions reduction, recycling) and be a model for local governments.
Oregon	Decisionmaking framework that combines context-sensitive design with sustainability principles. Conducts efforts to address climate change through both internal and external practices that address vehicle miles traveled and system efficiencies; formed a Climate Change Executive Group and Climate Change Technical Advisory Committee to establish priorities and guide Oregon Department of Transportation activities; recognize importance of land use planning and multimodal planning for mitigation.
Pennsylvania	Training program to educate employees on linkages and overlaps between planning and National Environmental Policy Act (NEPA) to streamline both processes.
Vermont	Preventative measures to address impacts of air quality and climate change, including both mitigation and adaptation approaches; involves coordination with local governments, state agencies, and neighboring states.

Source: Adapted from stakeholder interviews and research (Georgia Tech Research Corporation, 2011).

In particular, the growing emphasis on climate change has been a leading driver of state involvement in developing sustainability-related programs. For example, almost one-third of the state DOTs has some involvement with a climate change initiative. By 2011, more than 35 states had climate action plans and more than 10 had adaptation plans; state and regional transportation agencies typically contribute to those plans (Georgia Tech Research Corporation, 2011). From a sustainability point of view, these plans are important, because they inject new concepts into the intersection of transportation-environment planning and require a coordinated, multiagency, multijurisdictional approach to planning.

In terms of the economic element of the TBL, state attention is focused heavily on developing mechanisms to fund transportation infrastructure, rather than on the broader health of the economy. In this regard, several states are developing tools and processes to help assess the long-term financial sustainability of transportation assets, as shown in Table D-4.

There has been much less progress in incorporating the social element of the TBL into sustainability initiatives. In large part, this is due to the difficulty in defining social sustainability or to a lack of appropriate data. Most DOTs have addressed this issue via environmental justice (EJ) and context-sensitive solutions (CSS) policies, although some states are attempting to move beyond this.

In the interviews conducted by the research team, many practitioners felt that the TBL framework was inadequate and needed to be expanded to consider a broader definition of sustainability. In particular, the idea of fitting technology and technology impact assessment into the TBL (which is often addressed via the economic element of the TBL) was deemed important. Many practitioners saw technology as a critical driver that needed to be better understood and managed if true sustainability was to be achieved.

Other issues that emerged in terms of the definition of sustainability were the issues of financial or fiscal sustainability and the importance of system preservation. Under this concept, a budget proposal must consider additional dimensions:

- **Benefit and ROI—**contribution of the proposal to the performance of the overall transportation system with acceptable ROI expectations.

Table D-4. Sample economic and financial sustainability tools and initiatives.

DOT	Practice	Description
Illinois	Program Menu	Develops funding packages based on different emphases (e.g., system preservation or capacity for economic development) and uses iterative process to allocate all available funding and meet statewide transportation needs.
Illinois	Life-Cycle Costing (LCC)	Process to assess present and future roadway condition and prioritize improvement projects; based on a facility's cost over its lifetime rather than just the upfront capital costs.
Montana	Performance Programming Process (P3)	Decision process for funding allocations based on asset management principles, scenario planning, and strategic goals.
Montana	Highway Economic Assessment Tool (HEAT)	Enhanced cost–benefit analysis tool for projects that accounts for system impacts at state, corridor, and project level; considers traditional mobility measures in addition to economic and resource impacts; tool is customizable to each state's goals and data availability.
Oregon	Investment Scenarios	Oregon Transportation Plan assesses seven policy scenarios and three investment scenarios to determine system performance outcomes of different levels/types of investment.

Source: Adapted from stakeholder interviews and research (Georgia Tech Research Corporation, 2011).

- **Solvency—**the ability of the proposed project or investment to contribute to the overall ability of the government to meet long-term financial obligations.
- **Growth—**the ability of the proposed project or investment to help sustain economic growth.
- **Stability—**the capacity of the proposed project or investment to improve governments' ability to meet future obligations within existing or projected tax burdens.
- **Intergenerational equity—**the capacity of government to pay current obligations without shifting the cost to future generations.

Some interviewees suggested emphasizing fiscal sustainability may be a way to make the whole concept of sustainability appealing to the larger community of state and local government officials and general public. Fiscal sustainability requires a much broader understanding of the total costs and benefits of any public project. For example, if a road project imposes additional costs on other parts of the infrastructure or forces the state to incur additional costs (e.g., additional expenditures associated with nonattainment of clean air standards); those costs would be included in the overall cost–benefit analysis of the project. The project would then have to demonstrate sufficient benefits to the state to overcome the additional cost. Furthermore, techniques such as Total Cost Accounting (TCA) would go a long way toward allowing state programs to consider long-term or intergenerational costs.

Best Practice Example: Oregon's Sustainability Mandates

- **Executive Order 00-07:** Promoted sustainability in state government operations, primarily through the adoption of certain practices by the Department of Administrative Services.
- **The Oregon Sustainability Act:** Provides state agencies with 10 objectives for conducting their internal operations and 10 objectives for carrying out their missions to support sustainable communities. Created the Oregon Sustainability Board to provide oversight to sustainability efforts in the state.
- **Executive Order 03-03:** Broadens the scope of state agency sustainability planning efforts. It supported the Oregon Sustainability Act and directed 20 of Oregon's larger agencies (including ODOT) to designate a sustainability coordinator and write a sustainability plan.
- **Executive Order 06-02:** Reaffirmed agency sustainability planning process and created several interagency teams to address specific sustainability initiatives, such as GHGs, purchasing, electronic waste, and energy. This executive order also addressed sustainability in the private sector and in Oregon's university system. It reauthorized the Oregon Sustainability Board and rescinded earlier sustainability executive orders.

One of the current leaders in integrating sustainability into its operations is the State of Oregon. Since 2000, Oregon's governors and state legislature have mandated sustainability objectives for state agencies. In response, the Oregon Department of Transportation (ODOT) has developed one of the most extensive sustainability plans in the United States. It includes both short-term goals and longer-term goals to be achieved by 2030 (Fordham, 2008). In addition, ODOT has gone far to institutionalize the concept of sustainability through the development of an integrated, strategic sustainability program. This program provides central oversight and coordination and is a resource to staff incorporating sustainability goals into their work. The program crosses all divisions and addresses both internal support functions and the external transportation system.

Organizationally, ODOT's sustainability program manager is located in the director's office and reports to ODOT's chief of staff. The manager has broad responsibility to analyze all aspects of the agency's internal and external operations and to identify opportunities to integrate sustainability principles into agency decisionmaking, management, and operations. The manager is responsible for development and implementation of the Sustainability Plan. The organization of ODOT's sustainability program is depicted in Figure D-1.

The ODOT Sustainability Council, an internal group of managers appointed by ODOT's director to represent a variety of functional areas and geographic locations, meets quarterly to

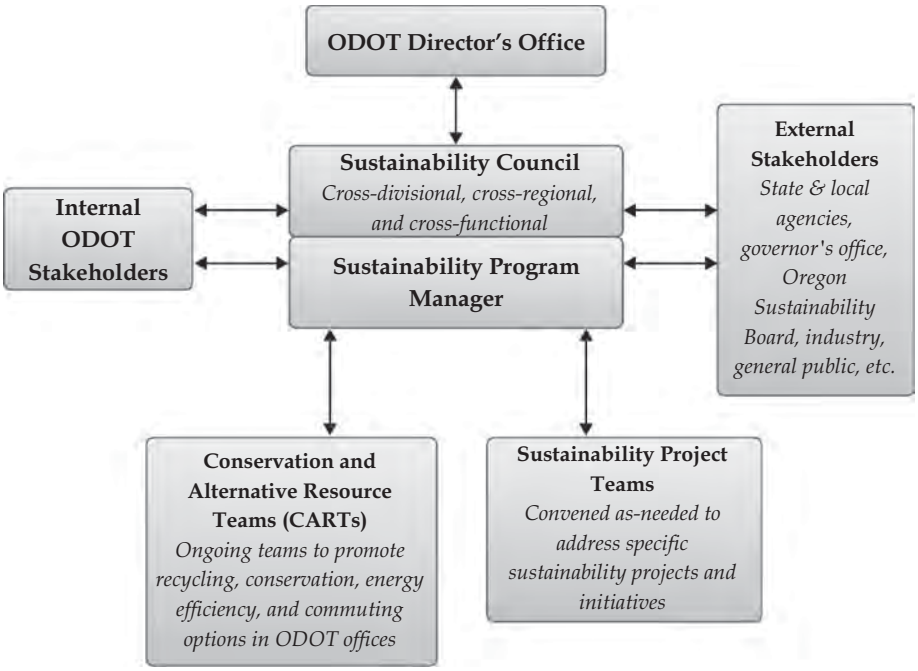


Figure D-1. ODOT sustainability program organization.

provide oversight to the plan and the program. This group approves and monitors sustainability work items and recommends policy and practice changes to the director.

Conservation and Alternative Resource Teams (CARTs) act as office "green teams" for the agency, supporting the overall sustainability program by implementing on-the-ground initiatives in ODOT facilities. CARTs educate employees about work-related efficiency efforts and promote voluntary participation in those efforts to create a culture of resource conservation awareness.

Sustainability project teams are convened, as needed, to address specific sustainability projects and initiatives. These teams may be formal groups that meet regularly or informal collaborations of staff that meet only to address a particular need. Teams have worked on internal GHG emissions tracking, neighborhood electric vehicles, fleet use of biodiesel, vehicle emissions issues, and other initiatives.

In addition, the Oregon Sustainable Transportation Initiative (OSTI) is a coordinated effort by Oregon state agencies to explore ways that the state, MPOs, and local communities can significantly reduce GHG emissions from the transportation sector to help offset effects of global climate change and foster energy independence. OSTI is a partnership among ODOT, the Department of Land Conservation and Development, the Oregon Department of Energy, and the Oregon Department of Environmental Quality, which grew out of two legislative directives: HB 2001 (2009)/The Jobs and Transportation Act and SB 1059 (2010)/Section 85 Oregon Laws.

California offers another example of efforts to integrate sustainability into a DOT operation. The California Transportation Plan (CTP) is a statewide, long-range transportation plan for meeting future mobility needs. The CTP defines goals, policies, and strategies to achieve the collective vision for California's future transportation system and emphasizes what the California Department of Transportation (Caltrans) calls the three "E's of sustainability:" environment, economy, and equity. Caltrans served as a pilot program using EPA's Smart Mobility Framework

(SMF) to develop an approach to implement this plan. Specifically, SMF provides a tool to assess how well plans, programs, and projects meet Smart Mobility principles and objectives (Georgia Tech Research Corporation, 2011).

The SMF is organized around six principles (Georgia Tech Research Corporation, 2011):

- **Location efficiency.** Integrate transportation and land use in order to achieve high levels of nonmotorized travel and transit use, reduced vehicle trip making, and shorter average trip length, while providing a high level of accessibility.
- **Reliable mobility.** Manage, reduce, and avoid congestion by emphasizing multimodal options and network management through operational improvements and other strategies.
- **Health and safety.** Design, operate, and manage the transportation system to reduce serious injuries and fatalities, promote active living, and lessen exposure to pollution.
- **Environmental stewardship.** Protect and enhance the transportation system's emission of GHGs.
- **Social equity.** Provide mobility for people who are economically, socially, or physically disadvantaged to support their full participation in society. Design and manage the transportation system to distribute its benefits and burdens equitably.
- **Robust economy.** Invest in transportation improvements that support the economic health of the state and its local governments, the competitiveness of California's businesses, and the welfare of California residents.

The Smart Mobility principles will be integrated into Caltrans' day-to-day operations. The principles will be introduced into a wide range of DOT and partner activities, including planning and programming, standards and guidelines, transportation projects and programs, development and conservation projects and programs, decision support, and performance measures.

The SMF guidebook establishes priorities and provides tools for beginning to implement Smart Mobility at Caltrans and partner agencies. This section will describe two of those tools: the Smart Mobility action plan/checklist and place types. The action plan identifies the concepts, methods, and resources essential for implementation of the SMF; it identifies 10 implementation themes:

- Increase the impact and effectiveness of the SMF and the call to action by widely disseminating information.
- Support an expanded Interregional Blueprint Planning program.
- Integrate the SMF consistently into Caltrans policy and practice.
- Integrate the SMF policy and practice with activities of other agencies and departments, such as the Strategic Growth Council and Senate Bill (SB) 375.
- Collect, develop, and use data and tools needed to implement the SMF, including performance measures.
- Revise planning and programming procedures to reflect the SMF.
- Revise design standards and procedures to reflect the SMF, starting with revision of the *Caltrans Highway Design Manual* and implementation of the department's Complete Streets policy.
- Undertake major cross-functional initiatives, such as a comprehensive program to ensure strong consideration of location efficiency factors in newly developing areas, and a funding initiative to identify adequate resources for transit and rail capital investment and operations.
- Integrate the SMF into local government land use and transportation planning and implementation activities.

- Encourage local government Smart Mobility implementation assessment and evaluation activities, such as advancing the use of multimodal level of service (LOS).

The action plan is presented as a checklist of high-priority activities for implementation and identifies the relevant level(s) for implementation (state, regional, local). Caltrans anticipates that several important outcomes will be achieved over the long term:

- Improved accessibility
- Reduced average length and number of trips
- Social equity
- Reduced environmental impacts of travel
- Improved public health
- Reduced energy costs and vulnerability to price escalation
- Economic development.

Thus, the SMF provides a mechanism for integrating short-term actions into long-term sustainability.

A major concern identified by interviewees was ensuring that sustainability was customized to different settings. The SMF addresses this issue and identifies seven "place types" that represent generic development patterns throughout California: urban centers, close-in compact communities, compact communities, suburban areas, rural and agricultural lands, protected lands, and special use areas. The SMF provides guidance for how Smart Mobility may be implemented in each place type, offering resource documents and example guidelines for each, grouped into planning, transportation projects and programs, and development and conservation projects and programs (Georgia Tech Research Corporation, 2011).

Funding and Needs Assessment

Funding and sustainable source(s) of funding were major issues emerging from practitioner interviews. Although some interviewees recognized the need to incorporate sustainability considerations into budgeting processes, even within an environment of constrained resources, most agreed that new funding sources were needed for TBL sustainability to be institutionalized. Furthermore, there was a general consensus that as financial resources became more constrained, there should be a move toward more user fees and a greater emphasis on prioritization and self-funding.

Interviewees stressed the need for more flexibility in setting regional and local priorities and, of course, the need for more funds to manage current service requirements, while investing in forward-looking initiatives. Opinion favored having more regional and local control of revenue generation and use of funds. Self-funding transportation meant having more to do with controlling where, how, and how much revenue is collected, and where decisions are made that determine how and where funds are used, and for what purposes, modes, or programs, etc.

There are a large number of successful international examples of how to raise money to fund sustainability implementation. For example, in 1997, Denmark replaced its fixed annual vehicle ownership tax with a variable vehicle tax based on fuel efficiency. This policy, known as the "Green Owner" fee, required that owners pay €200 ($266.70) for a gasoline car with a specific fuel consumption of 6.5 L/100 km (36 mpg), with the rate increasing by €100 ($133.35) for every additional liter of consumption per 100 km. This meant an average 8.5 L/100 km (27.7 mpg) car would be assessed €400 annually ($533.40) (Whitelegg, 2003).

Internationally, perhaps Singapore has gone farthest in the area of sustainability-based user fees and funding. Singapore, which has a population of approximately 5 million and a land area of 270 mi^2, first implemented an area-based road pricing system in the 1970s. By 1998, the system was fully automated through the use of prepaid smart cards. Initially, the goal of this policy was simply congestion relief; however, it has since moved to full externality pricing. The basic price for the road fare is proportional to the target-speed that has been estimated to optimize traffic flow. If the average speed drops, the fees increase and vice versa. The fees are revised every third month, specified on electronic billboards at every gate, and communicated to drivers directly via smartphones and other electronic means. These fees are then modified based on the type of vehicle and estimated emissions. For example, electric vehicles pay a 20 percent lower road fee and hybrid vehicles pay a 10 percent lower fee. Revenues from this system produce approximately $50 million to $70 million per year (Gordon, 2005).

There is a broad consensus within the transportation community that the current system of transportation funding is broken, and that some form of user charging is needed to fund the future development of federal, state, and local transportation systems (Committee for the Conference on Introducing Sustainability into Surface Transportation Planning, 2005). In other terms, new revenues are needed, as well as a more effective system for flowing those funds to the right transportation investments.

Technology, shrinking government budgets, and public hostility to across-the-board tax increases all make some form of user fees potentially appealing; however, schemes like those adopted in Singapore, Denmark, or other foreign countries are difficult to implement in the United States. Attempts at implementing congestion zones and similar concepts are highly controversial and complex. Implementing advanced user-fee revenue generation systems, such as vehicle miles traveled charges may be decades away, and states are only beginning to test public reaction. For example, Minnesota's Department of Transportation tested mileage-based user fees. The Minnesota Road Use Test asks 500 people from two counties to test technology that could someday be used to collect a mileage-based user fee. Thus, while there are many promising ideas for future funding of the road system, agreement on new funding mechanisms is still very unclear. Minnesota's efforts build on earlier work completed by Oregon. In 2006, ODOT launched a 12-month pilot program designed to test the technological and administrative feasibility of this concept. The program included 285 volunteer vehicles, 299 motorists, and two service stations in Portland. The pilot program showed that, using existing technology in new ways, a mileage fee could be implemented to replace the gas tax as the principal revenue source for road funding. At the conclusion of the pilot program, 91 percent of pilot program participants said that they would agree to continue paying the mileage fee in lieu of the gas tax if the program were extended statewide (Whitty, 2007). There is also broad consensus on the need to develop guidelines to assist transportation agencies in making the case for new funding structures and to institute revenue collection sources.

Any move toward greater sustainability would require major changes in how states budget and account for transportation programs, specifically (1) the development of a more integrative cooperative budgetary system, (2) accounting for full social costs, and (3) greater flexibility in resource allocation.

The first of these elements poses the biggest challenge to transportation budgeting systems. Budgetary reform has a long history in the United States (Tyler and Willand, 1997). Table D-5 shows some of these initiatives. In general, such initiatives have had limited success. A budget process, in which budget developers estimate the long-term intergenerational impact of different investments on the TBL, in concert with the impact of spending on other agencies, is likely

Table D-5. Budget reform initiatives in the United States.

Period	Budget Idea	Emphasis
Early 1900s	Line-item budget Executive budget	Control
1950s	Performance budget	Management Economy and efficiency
1960s	Planning, programming, budgeting system (PPBS)	Planning Evaluation Effectiveness
1970s and 1980s	Zero-based budgeting (ZBB) Target-base budgeting (TBB) Balanced-base budgeting (BBB)	Planning Prioritization Budget reduction
1990s	New performance budget	Accountability Efficiency and economy

Table D-6. Project accounting approaches.

Project Costing Approaches	Definition
Total Cost Accounting (TCA)	TCA was introduced in the late 1980s in response to pressures to reduce the impact of industry operations on the environment. It is a cost estimation method that focuses on in-company assessments of cleaner production investments. TCA can be described as a normal, long-term cost accounting method, which pays special attention to hidden, less tangible costs and liability. Liability costs include fines for future damage involving environmental cleanup, healthcare costs, and property damage. Less tangible costs involve reduced consumer acceptance, tarnished corporate images, and strained external relations. Specifically, the TCA method focuses on the risks and hidden costs associated with a product or activity.
Full Cost Accounting (FCA)	FCA is distinguished from TCA. FCA includes an additional category of costs that should be accounted for, namely, *the social external costs* related to production, use, operations and maintenance (O&M), and disposal, which are not accounted for by any of the life-cycle actors or participants.
Life-Cycle Costing (LCC)	LCC is a process for evaluating the total economic value of a project by specifically addressing initial and discounted futures costs, such as O&M, rehabilitation and reconstruction, restoration and resurfacing, and other costs that are likely to be incurred during the life of a project.
Life-Cycle Cost Environmental Accounting (LCEA)	LCEA attempts to assess the full life-cycle costs, including costs (and benefits) associated with the environmental impact of the project (both the direct and indirect costs of the environmental impacts caused by the project throughout its entire life cycle).
Sustainability Life-Cycle Accounting (SLCA)	SLCA goes beyond the other forms of accounting for project costs by attempting to estimate the full sustainability (i.e., TBL net costs) of all potential project alternatives in addition to the conventional life-cycle costs. At the extreme, SLCA attempts to assess the full value added to society (including transportation and nontransportation impacts) as a whole. Additional SLCA goes beyond the full life-cycle window and considers very-long-term costs and what long-term options are foreclosed by the selection of a specific option. SLCA is similar to ROI but does not attempt to account for the benefits a project might provide and focuses on costs.

to be of limited success given the performance of previous budgetary fads and the general competitive nature of U.S. budgeting processes. Tools that are better able to evaluate the impacts of specific spending are discussed in the following paragraphs.

Numerous techniques exist to better capture the full social, environmental, and economic cost of proposed investments, as summarized in Table D-6.[D2]

[D2] "Project" in this section refers to major transportation projects, preservation, and any other significant campaigns and initiatives.

The techniques identified in Table D-6 can apply to capital programs and system preservation activities and can be arrayed in terms of a number of dimensions—specifically, the range of impacts included (e.g., project costs only, economic costs, environmental costs) and the degree to which long-term and/or full life-cycle cost is included (Figure D-2).

As can be seen, this matrix divides tools into those that focus on how costs are allocated and those that focus on the range of activities that are covered. In general, as agencies move toward a greater emphasis on sustainability, they would move from the bottom left side of the quadrant toward the top right corner. These cost–benefit techniques can be combined to move toward a sustainable budgeting or resource[D3] allocation system. Under this system, needs would be identified in the needs assessment process and converted into specific plans. These plans would be cost-estimated using Sustainability Life-Cycle Accounting (SLCA), and the results would be compared to identify the highest possible net TBL benefit to society over the long term.

Under this model, agencies can consider four complementary approaches for bolstering sustainability. One would be to construct long-term fiscal scenarios using cutting-edge socioeconometric techniques, such as generational accounting and present-value accounting. Second, agencies could extend baseline projections beyond the medium term using methods that have been applied in medium-term frameworks. Third, agencies could estimate the impact of current policy changes on the long-term fiscal outlook. Finally, agencies could reconfigure fiscal risks so that a greater portion is shared by households and current generations. It has been proposed that sustainability-based budgeting requires a greater degree of independence than conventional budget tasks and should, therefore, be conducted outside of government (Schick, 2005). In the context of a sustainable society policy system, the research team suggests that fiscal risk is cross-cutting and at least partially outside of government structures as known today

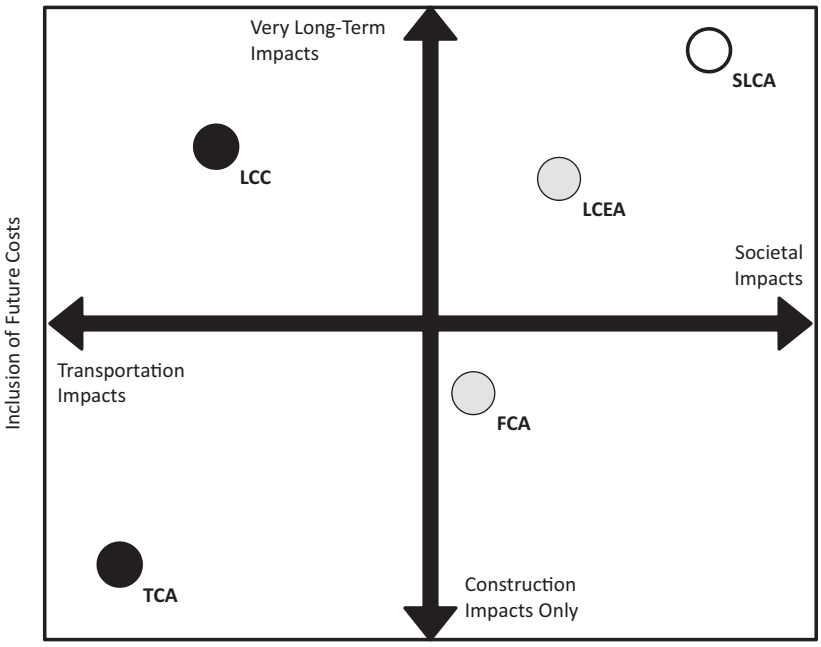


Figure D-2. Project cost accounting techniques array according to range and inclusion of future costs.

[D3] Any and all resources, including funds, staffing, equipment, materials, facilities, and intellectual capital.

and could include multiple agencies, as well as authorized commissions or bodies representing major economic and social sectors. A self-supported transportation system based more heavily on regional user charging may add considerable weight to the need for participation of multiple agencies and outside-of-government entities to budgeting and allocation decisions affecting all three bottom lines.

> One of the key concepts in sustainability budgeting is that resource allocation must be flexible and resources allocated to achieve the optimal sustainable state consistent with the agency's project and mission. Thus, project funding should not be limited to specific funds or accounts. Rather, funding should be able to flow freely between accounts. Furthermore, sustainable resource allocation requires that budgeting and resource allocation not be limited to specific agencies, transportation modes, or geographic regions. Thus, transportation resource allocation and budgeting should be approached as a whole and resources allocated to achieve the optimal sustainable return. (Cutcher-Gershenfeld et al., 2004)

Practitioner interviews revealed that budget and spending flexibility were critical to institutionalizing sustainability. Specifically, interviewees cited challenges created by federal transportation spending restrictions and the lack of flexibility in using these funds. These comments were interpreted to mean that the user community would directly fund transportation in several ways that are more directly tied to demand and use—and that the same community (i.e., the regional public, via commission or representative government) would exercise more direct control of major allocation decisions. This control of priorities could overarch and direct the particular agencies responsible for executing chosen programs—whether the programs are transportation, environmental, social, or otherwise.

For instance, in the Netherlands, the Ministry of Infrastructure and the Environment was formed to maximize the potential for efficient resource allocation by merging the former Ministry of Transport, Public Works, and Water Management and the Ministry of Housing, Spatial Planning, and the Environment. Now the Dutch have one ministry that has authority over regulation, management, and capital investments of transportation of people and goods via roads, trains, boats, and airplanes. In theory, the new ministry's budgeting decisions are made without reference to individual modal organization biases and allocate funds based on overall transportation goals.

Similarly, in Australia, decisionmaking processes in the state of Victoria were remodeled by the Transportation Integration Act of 2010 to create a new framework for the provision of an integrated and sustainable transportation system in Victoria. Now, the Victoria Department of Transportation oversees and coordinates the activities of all state agencies that impact the transportation system in Victoria, including heavy and light rail systems (including trains and trams), roads systems, all vehicles (including cars, trucks, bicycles), ports and waterways, and some air transportation systems. As with the Netherlands, the Victoria model is intended to promote integration between modes and drive transportation priorities toward common sustainability goals.

The core of Victoria's Transportation Integration Act is the high-level policy framework for setting sustainability policy. The key features of the framework are the six transportation system objectives and seven decisionmaking principles. The policy framework applies the principles of sustainability to the transportation sector and recognizes that transportation contributes a broader policy goal of achieving sustainable development, both locally and globally.

Specifically, the Act sets the following six objectives for the transportation system:

- Facilitate social and economic inclusion
- Encourage economic prosperity
- Support environmental sustainability
- Encourage the integration of transportation and land use

- Support efficiency, coordination, and reliability of transportation assets
- Promote safety and health and well-being

In terms of decisionmaking and resource allocation, the Act identifies seven key decision-making principles:

- Integrated decisionmaking
- Regular TBL assessments
- Specific inclusion of equity conditions
- Consideration of transportation system user perspectives
- Consideration of the precautionary principle
- Ongoing stakeholder engagement and community participation
- Decisionmaking transparency

Transportation agencies and interface agencies can use these principles in the formation of their own objectives when exercising their powers and performing their functions. In addition, the Act establishes requirements for need identification, plan development, and budget management that specifically address each of the six objectives. It should be noted that, as of 2012, it is too early in the life of the Transport Integration Act to judge its effectiveness in influencing the Victorian transport system and no structured evaluation has been conducted.

Sustainability, Resource Allocation, and Intergenerational Equity

A major difficulty in accounting for the cost of projects in the context of sustainability is the inclusion and evaluation of intergenerational equity or environmental justice. The origin of the concept in modern debate goes back to the work of John Rawls in the 1970s. Rawls developed a complex thought game based on social contract theory where rational individuals were asked to determine the rules and structure for a society without knowing where they were located in that society in terms of wealth and social position or the resources that society had at its disposal (each participant had some random chance of being assigned a role as "wealthy," "middle," or "poor," but they had no knowledge at the time they constructed rules; Rawls, 1971). Through a series of logical arguments, Rawls proposed a series of rules that participants would then generate to create a "fair" society. In this game, Rawls rejected the Benthamite approach (i.e., the greatest good for the greatest number) and, using a social contract approach, argued that decisions concerning public goods should be at least partially evaluated in terms of the welfare impacts to the least-well-off group.

In terms of intergenerational equity, Rawls put forward the "just saving principle" to help deal with the problem of looking after the least-well-off in future generations. According to this idea, saving (i.e., capital accumulation) should be encouraged via laws or cultural norms over current period consumption. This implies that consumption and economic well-being of the current generation should be limited in order to save resources and raise "the standard of civilization and culture" to a certain level. This would ensure that future generations would benefit from that accumulated capital and also any social/environmental benefits of de-emphasizing consumption.

The rationale for this is that in Rawls' thought game, all members of a society have equal claims on the aggregated resources of the group. The game also requires participants to include future members of the society as well as current members. Thus, if the participants chose to allow the current generation to consume all the nonrenewable resources available and leave behind no net savings or accumulated capital, future generations have no opportunity to use or benefit from those resources. According to Rawls this would be an unjust taking of resources by one group (i.e., the current generation) from another group that was not able to influence or participate in the decision to use these resources (i.e., future generations).

In terms of sustainability, discussions about the difficulties associated with fair intertemporal resource allocation have given rise to a large body of literature in recent years (which builds

in many ways on the economic literature on intertemporal consumption). This literature has focused on budgeting, environmental protection, and economics. [For examples of literature on budgeting, see Strow and Strow (2010). There are many texts on the integration of environmental concerns with intergenerational fairness, but for a starting point, see Portney and Weyant (1999). For examples of economics literature on sustainability, see Beder (2000).] In general, this literature has identified several approaches to intergenerational equity.

The first is the preservationist model, in which the present generation does not destroy or deplete resources or significantly alter anything; rather, it saves resources for future generations and preserves the same level of quality in all aspects of the environment and society [A good discussion of this topic can be found in Passmore (1974) and Norton (1986)]. At the extreme, this model requires an unchanging status quo where future generations benefit at the expense of current generations (i.e., current generations do not use their resources to improve their current well-being). Furthermore, considering that natural changes are inevitable, a growing level of resources would be needed to maintain the world in its current state. This requirement for capital replenishing would actually harm the well-being of the current generation as a greater and greater volume of their consumption would have to be diverted into investment to maintain the current state. Ultimately this could lead to a society where a majority of its resources are channeled into preserving a static condition in a world that constantly changes.

While this model seems unrealistic, its underlying principles can be found in a number of public programs. For example, numerous state parks programs, and the original "organic act" for the National Park Service, call for parks to be maintained in their current state in "perpetuity." In addition, a number of historic prevention programs calls for specific historical or culturally valuable sites to be maintained in their current states in perpetuity for future generations to enjoy. This has led to numerous challenges for natural conservation organizations faced with the dual mission of encouraging access and use (by the current generation) and saving the resource for future generations [See Grand Canyon River Outfitters Association (2005)].

Variations of the preservation model that emphasize stewardship or conservation are more common. However, as with preservationist models, these approaches frequently lack the tools and heuristics to be able to identify tradeoffs between current and future use. Furthermore, the specific inclusion of conservation or stewardship in legislation as a necessary decision factor (e.g., in NEPA analysis) means that well-meaning decisionmakers are faced with incompatible requirements where they must simultaneously preserve one set of public goods (e.g., an endangered species) while attempting to provide for another such as the construction of necessary infrastructure. The research team recognizes that the regulatory implementation construct would need to be modified to ensure compliance from all sectors under the TBL sustainability policy system.

An alternative position on intergenerational resource allocation is the so-called "opulence" or "technology model" in which the current generation consumes all the resources that it requires and uses them to generate as much wealth as it can, either because there is uncertainty that future generations will exist or because maximizing consumption today is the best way to maximize wealth for future generations [See Barnett and Morse (1963) or Simons (1981) for classic statements of this position]. This model generally ignores long-term degradation of resources or argues that future technology and the growing wealth of society will enable future generations to address these issues with fewer burdens on their resources than current generations (it will be easier to fix this problem with future technology than it is with present technology). In many ways this is the default position for the United States today; most public policy is directed toward the increase of current income, wealth, and technology with the assumption that any resource problems created can be dealt with in the future by wealthier or more technologically

advanced generations. For example, mountain top removal (MTR) allows current generations to benefit from the coal mined in a low-cost manner. However, the Surface Mining Control and Reclamation Act of 1977 mandates that sites must be reclaimed to the land's pre-mining contour and use by the mine owner. Thus, the wealth generated by MTR is used to address an environmental problem created by MTR. In the context of the global literature on sustainability, this is a position that many theorists dislike.

Finally, there are economic models that focus on total life-cycle cost minimization. By using proper accounting and discounting techniques, it should be possible to estimate the full cost of different alternative investment and spending opportunities and identify the option that has the lowest costs across all time periods. In the United States, discounting is commonly used in regulatory or business case analysis in the federal government. For example, Circular A-4 of the U.S. Office of Management and Budget (OMB) mandates that all executive agencies and establishments conduct a "regulatory analysis" for any new proposal and, more specifically, a cost–benefit analysis. OMB Circular A-4 explicitly refers to the importance of equity for future generations and requires a "lower but positive" discount rate for projects with potential long-term impacts. Beyond this there is little guidance.

One alternative is the use of a "social discount rate," which calculates the net present value of a project's social costs and benefits over time (in some case, intergenerational) [See Baumol (1968), Harberger (1968), Arrow and Lind (1970), Bradford (1975), Auerbach (1982), Lind (1982), Arrow et al. (1996), Fuguitt and Wilcox (1999), Portney and Weyant (1999), and Tresch (2002)]. A positive net present value indicates the project increases efficiency or raises wealth in aggregate. It also means that the project produces sufficient benefits to fully compensate individuals for the forgone benefits of the resources it displaces from alternative uses. Debates on the use of the social discount rate for very-long duration investments are often highly technical but center around several key issues:

- How the opportunity costs of public funds should be addressed
- The degree to which the net benefits of government projects are reinvested or consumed
- The social rate of time preference
- The mechanism for compensating the generations that bear the costs of the project
- The role that risk and uncertainty should play in the analysis

For example, scholarly objections over the conclusions and methodology of the famous "Stern Review: The Economics of Climate Change" largely revolved around the discounting technique used and whether the discount rates were appropriate.[D4]

It is generally clear in the sustainability literature that greater attention needs to be paid to considerations for intergenerational equity in sustainability resource allocation discussions. While the tools do exist to conduct this analysis, there is no consensus as to how these tools should be used, the exact methodology to be followed, and the key assumptions that should be made. Until these issues are resolved, intergenerational accounting and resource allocation will remain controversial and difficult to incorporate into sustainability planning.

Another common lesson from the sustainability budgeting literature is that resource allocation is most effective when it is flexible; funding that is able to flow with minimal restrictions between accounts is easier to repurpose if that project raises new sustainability concerns. Since the point of incorporating sustainability into planning is to allocate the available resources to achieve the optimal sustainable state consistent with the overall purposes of project and mission

[D4] The Stern Review on the effect of global warming on the global economy has been a hotly debated topic amongst environmental economists since it was released by the British government on October 30, 2006.

of the agency, funding for projects should be flexible enough to be applied to projects and circumstances as they arise.

Furthermore, best practices in sustainable resource allocation emphasize that budgeting and resource allocation are most efficient when they are not limited to specific agencies, transportation modes, programs, or geographic regions. For these reasons, transportation resource allocation and budgeting should be approached in a holistic manner, and resources should be allocated to achieve the optimal sustainable return (Cutcher-Gershenfeld et al., 2004). For examples of budget and resource allocation flexibility, please see Section D.1.4.

Coordination and Planning

Many interviewees considered coordination as a major challenge because it is multidirectional, that is, horizontally between different departments within the state government and vertically between different levels of government. It was noted that unless state DOTs improve coordination of land use issues with local governments, there would be little hope of improving the sustainability of state transportation initiatives.

States recognize this challenge but are limited in the extent to which they can manage land use issues. A number of states have attempted to develop programs that coordinate land use and sustainability. At least 22 state DOTs address land use coordination, and one-third of them use access management as the primary tool. Each initiative involves coordination with other state-level agencies and/or local governments. Table D-7 summarizes these initiatives.

In many states, there has been an increase in the use of collaborative approaches in planning and management as a means of coordinating the efforts of state and local governments in transportation planning. For example, in 1990, the Washington State legislature passed the Growth Management Act (GMA). The GMA established the Regional Transportation Planning Program to create associations of local governments into Regional Transportation Planning Organizations (RTPO). RTPOs are designed to create a formal mechanism for local governments and the state to use in ensuring consistency and coordination in transportation planning and project prioritization for regional transportation facilities. Washington's regional transportation planning system comprises the Washington State Department of Transportation (WSDOT), 14 RTPOs, and 10 MPOs (Brody and Margerum, 2009).

Table D-7. Sample state land use coordination initiatives.

DOT	Description
California	Grant program for collaborative regional visioning and scenario planning that integrates transportation, land use, housing needs, resource protection, and other issues; communities shape their "Blueprints" process through selection of performance goals.
Montana	Transportation Impact Analysis tool and coordinated development review process for determining impacts and required mitigation.
New Jersey	Effort coordinated with New Jersey's Office of Smart Growth to emphasize reinvestment and transformation of existing transportation infrastructure; produced nationally recognized programs, including transit villages and mobility and community forums.
New York State	Smart Growth educational and training programs and planning assistance for local and regional transportation agencies; website to facilitate communication.
North Carolina	Coordinate transportation and land use planning efforts among several state and federal agencies; initiatives include a statewide action plan and development of a comprehensive shared GIS database.
Pennsylvania	State and regional agencies coordinate efforts for land use, transportation, economic development, and conservation to make effective investment decisions; DOT's Sound Land Use Implementation Plan is updated annually.

Source: Georgia Tech Research Corporation (2011)

Key highlights of the Washington transportation system include the following:

- **Organizational integration of RTPOs and MPOs.** RTPOs and MPOs use the same policy board for decisionmaking.
- **Formal statewide meetings of regional planning organizations.** WSDOT holds quarterly meetings for all the state's regional planning organizations to coordinate activities and information.
- **The Tribal Transportation Planning Organization (TTPO).** The TTPO was created to incorporate tribal participation into transportation planning and programming more fully.
- **Dedicated funding for planning a cross-boundary project.** WSDOT offers dedicated funding to RTPOs for projects that cross multiple RTPO boundaries.

Similarly, Iowa's transportation planning system is managed through a partnership involving the Iowa Department of Transportation, nine MPOs, and 18 Regional Planning Affiliations (RPA). In its initial regional transportation planning, Iowa delineated areas outside MPO boundaries into 16 rural transit regions, each of which was represented by a Council of Government (COG), and later established a new process based on the existing rural transit regions. The RPAs implement a relatively new method of collaboratively based regional transportation planning for Iowa by including local government in regional transportation planning, project prioritization, and funding.

Despite these initiatives, however, coordination between state and local governments remains one of the biggest challenges in developing a more sustainable state transportation system.

Data and Performance Measures

Data and performance measurement are vital to proper sustainability management. Progress cannot be measured until a system exists to measure performance and track change. Approximately 60 percent of state DOTs use performance measures or indicators that are related in some way to sustainability—that is, they mention environment, economy, and/or quality of life—and approximately 20 percent of DOTs use indicators for project prioritization, as shown in Table D-8.

As Table D-9 shows, these efforts are part of a much larger effort to develop sustainability measures.

Table D-8. Sample state DOT transportation and sustainability measurement frameworks.

DOT	Description
California	Reports on performance goals and measures at both the regional (Blueprint Planning reports) and state levels (annual reporting on nine performance outcomes from the California Transportation Plan).
Iowa	Annual report and online monitoring system that outlines performance goals and measures, and assesses which targets have been met; measures used to adjust allocation of resources and identify investments in priority corridors.
Minnesota	Framework using clear policy priorities, performance trend data, and performance forecasting to guide investment decisions; measures cover both internal and external activities.
Missouri	Quarterly report of measures for 18 outcome areas covering environmental responsibility and economic development since 2005; an additional goal added in 2009, to track impacts of stimulus funding.
Texas	Framework for sustainability measures that corresponds to goals in Texas DOT's strategic plan; current selection of measures was limited by data availability.
Washington	Quarterly report of goals and measures organized around WSDOT's five legislative and strategic policy goals (i.e., safety, preservation, mobility/congestion relief, environment, and stewardship) and a "Performance Dashboard" of key indicators; transparency and organized presentation make it useful for internal tracking and external accountability.

Source: Georgia Tech Research Corporation (2011).

Table D-9. Sustainable performance systems in the United States and other countries.

Source	Overview
U.S. DOT (2003). *Performance Report 2004 Performance Plan,* Washington, DC.	U.S. DOT defined five strategic goal areas covering safety, mobility, economic growth and trade, human and natural environment, and national security. For each goal, a set of strategic outcome goals and a number of more specific performance measures are defined for use in annual performance planning.
U.S. EPA (1999). *Indicators of the Environmental Impacts of Transportation,* updated Second Edition, Washington, DC.	The reports attempt to provide a comprehensive overview of the full range of environmental impacts (including impacts on air, water, climate, natural habitats, and other endpoints) from transportation modes (including road, rail, air, and sea) in a systemwide perspective (including impacts from production, use and scrapping of vehicles, and infrastructure).
Transport Canada (2001). *Sustainable Development Strategy, 2001–2003,* Ottawa, Canada.	The reports are structured around a set of seven challenges, broken down into 29 commitments, again broken down into targets and performance indicators. Three levels of indicators, reflecting different spheres of influence, include state-level indicators (describing the state of the transportation systems in terms of sustainability), behavioral indicators (describing the behavior or activities of the actors and stakeholders whose actions matter for the state of the system), and operational indicators (describing indicators for operations and actions of Transport Canada, itself).
Environment Canada (1991) and (2003). *Canada's Progress Towards a National Set of Environmental Indicators,* State of the Environment Rep. No. 91-1, Ottawa, Canada.	This report presents 43 preliminary indicators in 18 issue areas with widespread stakeholder and media interest. This uses a modified "pressure–state–response" framework and includes a fourth category related to the nature of human activity. The structure encompasses four sets of issues: ecological life support systems; natural resources sustainability; human health and well-being; and pervasive influencing factors.
NRTEE (2003). *ESDI for Canada,* Ottawa, Canada.	The NRTEE has developed a draft set of sustainable transportation principles that concern access, equity, individual and community responsibility, health and safety, education and public participation, integrated planning, land and resource use, pollution prevention, and economic well-being.
ORTEE (1995). *Sustainability Indicators: The Transportation Sector,* Toronto, Canada.	The report develops and assesses indicators for evaluating the impacts of possible actions or measures on the sustainability of the transportation system in Ontario. The framework adopted is based on a "criterion–influences–actions–measures" system. The conceptual model adopted is a computerized revised version of the "environment–economy linkages model."
TAC (1999), Ottawa. Canada.	TAC presents 13 principles pointing to sustainable transportation systems and related urban land use in Canada in 1993. A survey to monitor trends toward attainment of the principles can be considered as framing indicators or potential indicators to the extent that they provide appropriate quantitative responses.
Litman, Todd; Victoria Transport Policy Institute (VTPI) (2003). *Sustainable Transportation Indicators,* Victoria, Canada.	VTPI presents a literature review on its approach and selection criteria for sustainable transportation indicators. They offer an alternative perspective on the selection of transportation indicators by focusing on access (the ability to reach goods, services, or destinations) rather than on the transportation system's ability to "move vehicles" (by measuring traffic congestion, for example).
Centre for Sustainable Transportation (CST) (2003). *STPI,* Toronto, Canada.	The CST, Canada developed an initial set of 14 sustainable transportation performance indicators (STPI). They adopted four criteria to select the indicators: the indicators must (1) be relevant to the definition, (2) be relevant to a time series, (3) represent all of Canada, and (4) come from a reliable source. The direction of the graph representing time series numbers for each indicator shows whether progress has been made toward sustainable transportation.
OECD (1999). *Indicators for the Integration of Environmental Concerns into Transport Policies, Environment Directorate,* Paris, France.	The document pertains to the integration of environmental concerns into transportation policies through the development and use of indicators. The indicators are structured according to three themes: sectorial trends of environmental significance, environmental impacts of the transportation sector, and economic linkages between transportation and the environment.

Table D-9. (Continued).

Source	Overview
Environmental Performance Indicators (second ed.), World Bank, Environmental Economics Series, Paper No. 71.	The World Bank's Environment Department has prepared a manual on environmental performance indicators. This document discusses indicator frameworks, selection criteria for environmental project indicators, and issues to consider for various environmental areas.
PROSPECTS (2003). *Developing Sustainable Urban Land Use and Transport Strategies: Methodological Guidebook: Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems.*	The purpose of the report is as follows: (1) To present a coherent but flexible general approach to planning for a sustainable urban land use/transport system, building on the logical structure (2) To offer innovative methods of carrying out the steps of that logical structure, especially regarding appraisal of land use/transport strategies with respect to sustainability, and optimization with respect to sustainability (3) To provide detailed advice on a number of issues in the planning process.
European Environmental Agency (2002) TERM 2002—*Paving the Way for European Union (EU) Enlargement: Indicators of Transport and Environment Integration, Environmental Issues,* Copenhagen, Denmark.	The report describes the progress the EU is making toward the integration of environmental concerns into its transport policies. The aim is to monitor progress in three areas: the degree of environmental integration in the EU transport sector; progress toward transport systems that are more compatible with sustainable development; and the effectiveness of the adopted policy measures.
Baltic 21 (2000) Series No. 13/98: *Indicators on Sustainable Development in the Baltic Sea Region* (An Initial Set): Baltic 21 Transport Sector Report (No. 8/98). Annex 5: *Indicators for Sustainable Transportation,* Stockholm, Sweden.	Baltic 21 selects indicators according to three different types of goals and measures: (1) Indicators with regard to primary goals for sustainable transport (2) Indicators with regard to institutions, instruments, and measures (3) Indicators with regard to the transport system and transportation activity
DSD (2003). *Achieving a Better Quality of Life, Review of Progress Towards Sustainable Development,* United Kingdom.	The United Kingdom presents the 10 guiding principles: (1) Putting people at the center (2) Taking a long-term perspective (3) Taking account of costs and benefits (4) Creating an open and supportive economic system (5) Combatting poverty and social exclusion (6) Respecting environmental limits (7) The precautionary principle (8) Using scientific knowledge (9) Transparency, information, participation, and access to justice (10) Making the polluter pay
NZME (1999). *Proposals for Indicators of the Environmental Effects of Transport.*	The main purpose of the document is to provide the basis for agreement on the use of a core set of indicators to measure the environmental effects of transport. The components of the framework are as follows: (1) Root causes of transport activity (2) Indirect pressures (3) Direct pressures (4) State or effects indicators.

Source: Georgia Tech Research Corporation (2011).

Table D-10. Sample green transportation standards.

DOT	Description
New York State Department of Transportation (NYSDOT)	First completed rating system. Applied to DOT programs to recognize sustainable practices, encourage innovation, measure performance, and identify areas for improvement. Highest-level certifications and awards are announced annually on Earth Day.
University of Washington, CH2M Hill, WSDOT	Sustainability rating system for highways that includes 76 credits in seven categories, including 11 required credits. Draft version being tested and calibrated. Roadway developers will be able to apply for official certification or use the system for guidance.
Public–private initiative with support from EPA, FHWA, Maryland DOT (MDSHA)	Voluntary partnership to share information and provide guidance for developing more sustainable roadways.
INVEST, FHWA	Web-based self-evaluation tool with three modules: project development, O&M, and system planning; assigns each practice a point value (weight) according to its relative impact on sustainability.
Public/Private Team from Oregon and Washington	Rating system for transportation projects, plans, and employer programs that is under development.
University of Wisconsin with Wisconsin DOT	Approach based on TBL that uses qualitative measures to screen road projects and then rate them with quantitative measures.
Lochner Engineering	Checklist for sustainable highway/roadway projects that should be applied during planning, environmental assessment, design, and construction phases. Able to track how projects change.

Source: Georgia Tech Research Corporation (2011).

Closely related to the issue of performance standards is the use of green transportation standards for transportation investments. States have developed rating systems modeled after the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system for buildings. Table D-10 shows a sample of these standards under development.

Although all interviewees interviewed agreed that improved performance measures were needed, some opposed expanding or developing unnecessary new techniques, such as Sustainability Impact Assessments (SIAs). In fact, some feared a data overload—there may be too much data to choose from and the agency may struggle with what is the most important or most meaningful data to track. In addition, some interviewees were concerned about data availability. In general, there is substantial data available on environmental indicators (often required by law) and economic indicators (commonly used in transportation and travel demand planning), but it is difficult for state DOTs to develop meaningful indicators of social sustainability. Some states have tried to develop these indicators (e.g., Arizona, Delaware, and California) but have experienced considerable difficulty in narrowing down the list of potential indicators to a meaningful number. Furthermore, they have found that many of these indicators require original data collection, which can be extremely expensive. As a result, they have found it necessary to prioritize more pressing needs over data collection (Georgia Tech Research Corporation, 2011).

Culture Change, Outreach, and Communication

Interviewees conveyed a broad consensus that sustainability will require substantial culture change, both within agencies and with public and elected leaders. The latter form of leadership requires widespread public support to drive legislation, policy, and executive orders (EOs). These could create the needed framework for action by multiple agencies, to call for and support agency cooperation. The within-agency culture changes could occur as a top-down or bottom-up manner in particular agencies. The research team's view is that organization transformations usually work both ways but significant change is not easy or likely without top-level policy to require and support change.

In addition, the current fiscal and economic climate means that many agencies lack external support to engage in new initiatives. In general, stakeholders felt that there was a need to demonstrate that sustainability means saving money and resources in the long term, and as a more efficient means of delivering service. In particular, it was observed that changing the focus away from traditional LOS goals toward a focus on how transportation can improve community life and meet community needs. The need for new ROI tools that can reflect this expanded focus was noted.

Another important challenge articulated by interviewees was the difficulty of planning for and operating infrastructure across multiple jurisdictions.

Recently, several state DOTs have already begun to move away from the traditional LOS. For example, in response to a perceived lack of confidence from stakeholders, limited funding, employee turnover, and political pressure to outsource, the Louisiana Department of Transportation and Development adopted a new five-pronged approach (Bridges, 2008). First, it developed tools to demonstrate the ROI of any proposed change and identified changes that would improve performance and service delivery. Second, it engaged the department head as the chief sponsor of the initiative. He communicated forcefully that this was a "change-or-die" situation requiring maximum commitment. Multiple communication initiatives were launched to demonstrate the need for change and to explain the rationale, proposed changes, and how people could participate in the change. The program focused on quick wins, claiming "low-hanging fruit" and building momentum for change (Bridges, 2008).

Some governments have attempted institutional change through massive public participation programs. In Western Australia, the City of Perth provides an example of this process in action. In 2003, it began a broadly based consultation process to create a vision of the city. This process coalesced citizens, business groups, and more than 42 government departments to create a vision of Perth in 2030. As part of this exercise, a household survey was conducted of more than 1,700 households, and 1,000 citizens participated in a 1-day planning forum. Forum participants were grouped in teams of 10 and given a particular transportation problem. Each team was tasked with finding solutions to problems city planners faced involving sustainability, mobility, and economic growth. The result was a consensus plan known as "Network City," which was endorsed by all major interests involved. One of its major goals was to have 60 percent of all new construction be a part of a car-free, sustainable network of transportation (Schiller et al., 2010).

Figure D-3 shows two alternative models that the research team generalized from the literature review for building support for sustainability initiatives.

The top-down approach involves working with state leaders and key stakeholders to develop a consensus in favor of sustainability. Once consensus has developed and this support has been obtained, legislation or EOs can be enacted and the DOT can begin the process of changing its focus and culture and revise policies, programs, and processes to meet new sustainability mandates.

Under the bottom-up approach, cities and localities develop sustainable transportation initiatives. The literature on sustainability suggests that it is easier to build support for sustainability at a local level because transportation and issues related to quality of life primarily manifest themselves at the local level (e.g., congestion, lack of travel options) and it is generally easier, given the closeness to voters and less diverse interests, to develop consensus behind sustainability initiatives. If these initiatives are successful, they tend to generate attention from key state leaders and stakeholders. Localities then begin to adopt innovations to obtain the benefits they have seen from early adopters. Ultimately a consensus builds in the state that creating statewide programs may be appropriate and appropriate legislation and EOs may be put in place.

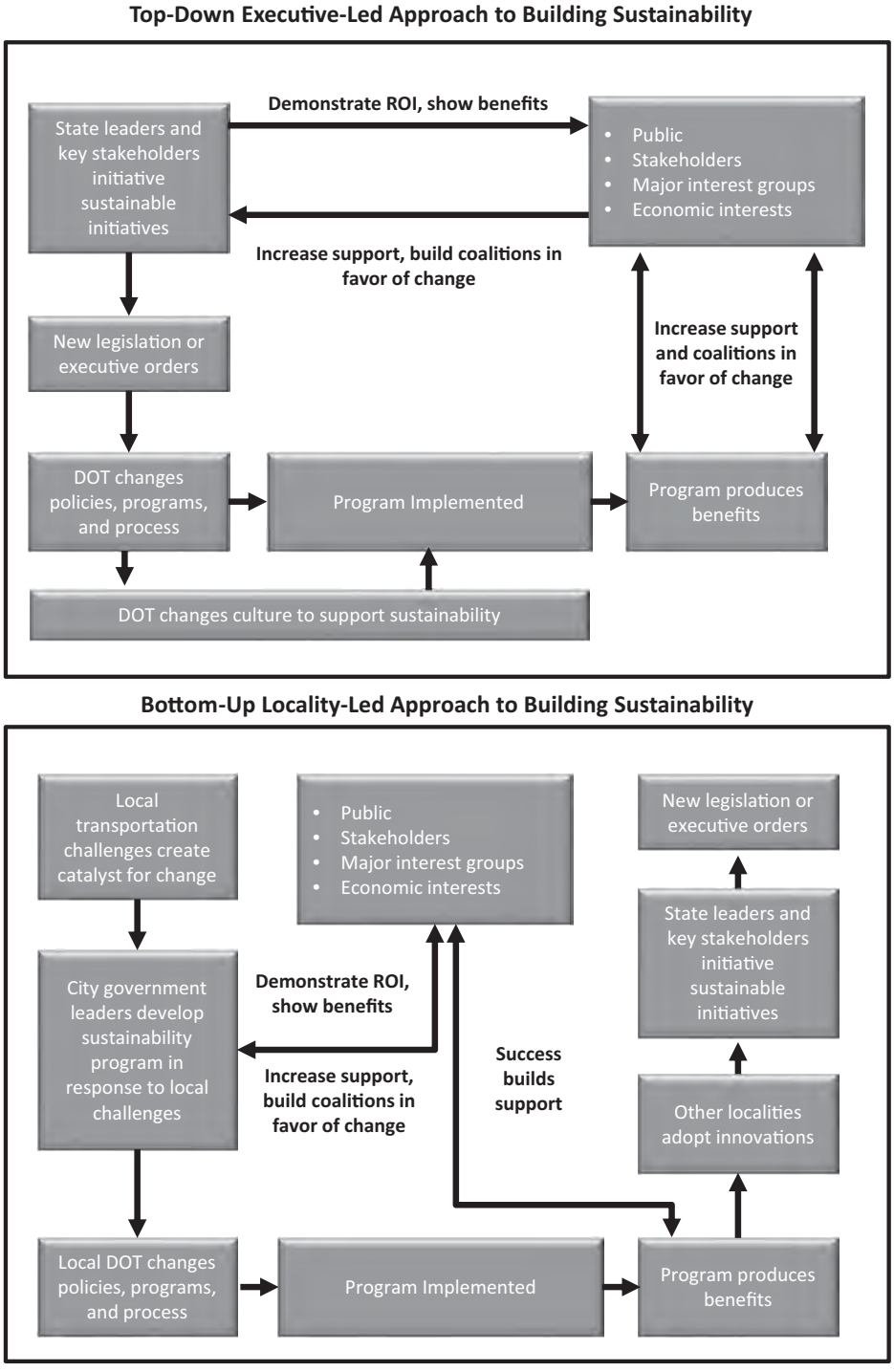


Figure D-3. Policy system development—top-down, bottom-up.

D.1.2 Local Government and City Sustainability Programs

Most of the sustainability literature concludes that cities and local governments are often leaders in government sustainability initiatives. There are many reasons for this:

- Cities experience many problems and challenges, often demanding a close integration of economic, environmental, and social policies. Thus, sustainability is a natural outgrowth of these efforts.
- The proximity of cities to the people and key stakeholders makes it comparatively easy to develop coalitions in favor of change.
- The powers that cities have to control or influence land use decisions provide them with the tools needed to implement sustainability.
- The close proximity of key stakeholders makes it easier for cities to develop new funding sources for sustainability initiatives, such as user fees, congestion charges, or bond issues to finance new transit.
- Cities are often the most economically dynamic and wealthy parts of a state or region. The concentrated wealth that cities generate gives them the material basis from which to embark on ambitious infrastructure projects.
- Although cities may be ethnically and culturally diverse, the relative breadth of diversity in terms of economic or transportation requirements is limited by the city's physical size. Unlike states, where the geographic size tends to create competing interests (e.g., Northern Virginia and Southeastern Virginia required increased transportation spending on urban systems, whereas rural Southwestern Virginia opposed spending on urban transportation and favored expanding the state highways system to support economic development), cities find it easier to unite interests around a common desire to address local transportation challenges.

Context-sensitive solutions (CSS) principles have been employed by state and local agencies for some time to reflect regional and local priorities for sustainability, livability, etc. in transportation decisionmaking. The methods and principles are important and well-accepted components of many DOTs' planning and project delivery processes, involving flexibility and recognition of project environmental and community context in project planning, design, and execution. CSS has provided significant benefits in fostering and improving citizen engagement in decision processes. It should be noted that local and city sustainability programs are not limited to large cities with strong economies. Table D-11 provides a sample of city and local government sustainability plans in the United States that include transportation for cities with fewer than 1 million people. As can be seen, these plans are not only focused on transportation.

Many large cities have developed comprehensive sustainability transportation programs, as well. The Smarter Cities project developed by Resources for the Future (RFF) identified some clear leaders [See National Resources Defense Council (n.d.)], profiled in the following subsections.

Boston, Massachusetts

Boston has become a leader in the development of sustainable transportation. For example, in 2009, Boston Mayor Thomas M. Menino established the city's Complete Streets program, a program intended to integrate automobiles, pedestrians, cyclists, and public transit. In pursuing this program, Boston has several advantages. As a dense, historic city built around a business, commercial, and cultural core with a long history of in-city settlement, it lends itself naturally to Smart Growth principles and more transit-oriented development (TOD). The public transit system is one of the largest in the United States and includes regional rail, subway, light rail, electric trolley buses, motor buses, and ferries. The existing rail system integrates the entire region, stretching to neighboring communities such as Cambridge, and other metropolitan areas such as Providence, Rhode Island, allowing commutes between these centers without relying on highways (Barmeyer, 2011a).

Table D-11. Sample local government sustainable transportation programs.

Location	Type of Plan	Scope	Time Frame
Burlington, Vermont	30-year Sustainability Action Plan	Economy, neighborhoods, governance, youth, and environment.	30-year plan; progress reports provide annual (short-term) success
Charleston, South Carolina	Action Plan	Energy, transportation, recycling and waste management, land use/ planning.	Unclear
Fayetteville, Arkansas	Comprehensive Land Use "Strategy" Plan	Land use planning–sprawl, infill, livable transportation growth, green network, traditional town form, attainable housing.	2025
Fort Collins, Colorado	Action Plan	Provides management tools for sustainable purchasing, healthy productive employees, green buildings, healthy ecosystems, sustainable energy, pollution and waste reduction.	Not stated
Northampton, Massachusetts	Comprehensive Plan	Social equity and economic vitality and environmental security for its citizens, the community, and its built and natural resources. Energy savings, waste management, green buildings, and green roofs.	10 years
Pasadena, California	Action Plan	Energy, waste, urban design, urban nature, transportation, environmental health, and water.	N/A
Sacramento, California	Action Plan	Solid waste, energy, and GHGs.	N/A
Santa Monica, California	Action Plan	Resource conservation, environmental and public health, transportation, economic development, open space and land use, housing, community education and civic participation, and human dignity.	2010; baseline of 2000 is used as comparison

Source: Virginia Polytechnic Institute and University (2008).

According to the Green Boston Climate Action Leadership Committee and Community's April 2010 summary report, *Sparking Boston's Climate Revolution*, by 2020 Boston should be able to reduce vehicle miles traveled in the city by more than 7 percent through promoting the use of public transit, as well as by fostering TOD and encouraging ridesharing, walking, and biking. Transportation initiatives account for 31 percent of the city's carbon reduction goals for 2020. These goals include both state and federal policies—such as a GHG standard to improve the fuel efficiency of vehicles—as well as many of Boston's own programs, such as increasing enforcement and education on anti-idling (Green Boston Climate Action Leadership Committee and Community, 2010).

For the past couple of years, Boston has been increasing bike usage through a city initiative that, among other things, added 30 miles of new paths. In fact, from 2007 to 2009, the city saw a 43 percent increase in bicycle ridership—more than three times the national average increase. In July 2010, the city was awarded more than $3 million in federal funding to establish one of the country's first bike-sharing systems. Often located near public transit stations, riders can borrow, use, and return a bike with just the swipe of a card (Barmeyer, 2011a).

Chicago, Illinois

The basis of Chicago's sustainable transportation efforts is Chicago's GO TO 2040, which was established by the Chicago Metropolitan Agency for Planning. The goal of the plan is to move the region to increase transit, fleet, and freight efficiency in an affordable and sustainable manner.

The plan is an excellent example of the way in which cities have the power to do small, low-cost initiatives that can produce major benefits. For example, in the areas of public transportation, minor changes, such as the Bus Tracker and Train Tracker systems provide major benefits. These systems provide real-time bus and train arrival information that can be accessed online, on mobile devices, or via text. Local businesses have the option of running Bus Tracker on a screen display or message board for the convenience of their customers. With Bus Tracker information free and accessible to the public, business owners can develop their own applications to display the information, or they can download for free the Do-It-Yourself Bus Tracker Display, available on the Chicago Transit Authority (CTA) website (http://www.transitchicago.com/).

Schweiger (2003) found several benefits to such systems, including the following:

- Reduced average waiting times for customers and increased willingness to wait due to real-time bus arrival information
- More frequent transit service use
- Increased ridership and revenue
- Shifting behavior toward public transportation.

Chicago is also increasing its support for increased use of electric vehicles. For example, Chicago is adding 280 electric vehicle charging stations, including in the suburbs. The stations will be located at the O'Hare and Midway airports, in downtown parking garages, grocery store parking lots, and toll plazas and will be ready to fully charge electric vehicles in less than 30 minutes. Chicago will be among the first to use the new recharging stations with its fleet of heavy-duty electric vehicles, such as electric-powered garbage trucks, which are slated to come online soon.

In addition, Chicago has designated nearly 40 charging stations for I-GO Car Sharing, a local nonprofit that will add solar canopies to its stations to power I-GO vehicles with clean electricity. I-GO, which views itself as an extension of the public transit system, became the first car-sharing service in the nation to offer customers a seamless integration with the region's public transportation system. In 2009, I-GO partnered with the CTA to give users access to I-GO cars and CTA bus and rail services with a single I-GO/CTA smart card.

Chicago is a key freight hub. Six of the country's seven largest railroad carriers have terminals in the Chicago metro region, bringing nearly 500 freight trains through the area each day. The freight traffic creates economic and industrial growth for the region—as well as pockets of congestion, bottle-necked traffic at rail crossings, and increased air pollution. To increase the sustainability of these initiatives, as well as increase the efficiency of freight movement in Chicago, the Chicago Region Environmental and Transportation Efficiency Program (CREATE) was initiated. CREATE is a public–private partnership between the U.S. DOT, the State of Illinois, the City of Chicago, six private rail companies, Chicago's commuter rail service Metra, and Amtrak. It has outlined a plan to strategically upgrade four widely used corridors, increasing capacity and improving rail network connections throughout the region. Of the 71 projects under way, 10 are complete. Fully implemented, the program is expected to create 172,000 jobs and prevent the equivalent of 1.61 million metric tons of carbon dioxide emissions each year.

In addition, 42 municipalities in Chicago's south suburbs were awarded $2.3 million in competitive federal funding through the Department of Housing and Urban Development's Sustainable Community Challenge Grant program to implement a multijurisdictional, rail-focused revitalization strategy. The plan emphasizes development around transit, intermodal freight industries, green manufacturing, and environmental stewardship and aims to attract 13,000 jobs and $2.3 billion in new income to the area over the next 10 years.

New York, New York

The New York metropolitan region's population density gives it a clear advantage in developing sustainability plans. This density has positioned New York to be served broadly by mass transit, accessible easily on foot and by bike, and to develop naturally by the principles of Smart Growth. Furthermore, with 19 million people living and working in the region, 3.6 million people commuting to the city daily, and 50 million tourists visiting annually, efficient and effective mobility programs are supported widely by voters and city leaders (Barmeyer, 2011b).

With nearly 50 percent of commuters using public transportation daily, New York has the highest percentage of transit users in the nation. Between 2000 and 2009, transit commuters increased by 4 percent, the greatest increase in the nation according to the report *State of Metropolitan America.* It is also one of only two regions in the United States, alongside neighboring Jersey City, New Jersey, with an average automobile ownership of less than one vehicle per household. Getting from place to place is more affordable in New York—at an average annual cost of $5,289—than in any other large city in the country. At an average of 9,920 miles per year, New York City residents travel fewer miles by car than residents in any U.S. city besides Jersey City.

The average New Yorker's energy consumption and carbon emissions are about one-quarter of that of the average American, and there is no question that the city's impressive transportation network is crucial to these results. The power largely behind many of these impressive results is the Metropolitan Transit Authority (MTA), which oversees a 5,000-square-mile region, including downstate New York, Long Island, and southwestern Connecticut. According to the MTA's 2008 sustainability plan, *Greening Mass Transit and Metro Regions*, MTA must reach at least two-thirds of New York's projected population growth of 4 million by 2030 for the metropolitan region to maintain its vitality and strong economy.

The high public transit use means lower energy consumption for the average New Yorker, because with 8 million riders each day, it is as though each of these people is driving a car with a fuel efficiency of 100 miles per gallon. It also means fewer carbon emissions. In 2008, MTA joined the Climate Registry, a nonprofit, third-party verifier of GHG emissions, which determined that for every unit of carbon emitted by New York public transportation, more than eight units of carbon are saved due to reduced driving by transit riders.

MTA is also expanding uses of renewable energy, partnering with various entities at the city and state levels on TOD, exploring new technologies for trains to recycle energy wasted during braking, and replacing overhead "necklace" lighting on bridges with LED bulbs.

Although MTA is responsible for public transit in the region, New York City has been a guiding force in the transportation future of the city with its PlaNYC for a "greener, greater New York." Since 2007, the City has added 200 miles of dedicated bike lanes, and bicycle commuters increased 26 percent from 2008 to 2009. In 3 years, it has completed 19 rezonings that have directed development to areas with good transit access.

San Francisco, California

San Francisco is a major public transit city. More than half of the city and county population commute via public or alternative transportation (e.g., bike, rideshare), and 90 percent of city residents are within two blocks of a public transit stop. Almost one-third of city residents get to work by train, bus, trolley, or cable car; 7 percent carpool, 10 percent walk, and 3 percent bike. A 2008 Commuter Benefits ordinance required employers to reward employees for carpooling or using public transit (Quinton, 2011b).

The achievement of this level of reduction in car use has been brought about by a close integration of city and transportation planners. City planners work alongside the San Francisco Metropolitan Transportation Authority (SFMTA) and regional partners to be sure transit services stay relevant as the city changes. The eastern neighborhoods are of particular concern, because unlike many parts of this densely populated city, they will likely see a huge population increase in the next few decades; current plans show an increase to 320,000 daily trips by 2035—50 percent more than in 2005. The plan ensures transit meets the needs of rapidly growing neighborhoods.

City and state GHG reduction targets have focused the region on improving transit networks and getting single-occupancy vehicles off the road. In 2004, San Francisco pledged to reduce carbon emissions to 20 percent below 1990 levels by 2012; in 2006, California committed to reducing GHG emissions 25 percent by 2020 and set a 20 percent reduction goal specifically for the transportation sector. To meet such targets, San Francisco's transit ridership needs "to be doubled," the SFMTA noted in its *2008 Climate Action Plan.*

SFMTA's investment in clean fuels will help lower emissions citywide. The electric trolley buses, streetcars, and light rail trains that compose roughly half of San Francisco's transit fleet already produce almost zero emissions. Not only are they electric powered, they are also powered by the city's hydroelectric plant, keeping fossil fuel use low. All SFMTA buses are either diesel or hybrid-electric models, and by 2020, SFMTA hopes to field an all-electric fleet. Switching nonrevenue vehicles, such as parking enforcement cars, to more fuel-efficient models will be SFMTA's next big project.

At the regional level, the Bay Area Metropolitan Transit Commission has committed to expand the regional bikeway network, increase funding for TOD projects, and integrate a Climate Action Program into regional transportation plans. The Metropolitan Transit Commission has already set aside money for a regional bike-share program, which will involve six cities along the Bay Area peninsula transportation corridor. The proposed development of a California high-speed rail network and initiatives to expand charging base stations for electric vehicles could further improve regional transit dramatically.

SFMTA's Livable Streets unit focuses on "improving quality of life for people on the streets who aren't in cars" (Quinton, 2011b). Livable Streets pioneered the "sharrow," a road marking that tells bicycles and cars to share a lane, and has timed traffic signals on a major thoroughfare so that bicyclists never have to stop at red signals. SFMTA's Livable Streets plan,

currently experiencing dramatic increases in demand, is complemented by the city's Better Streets Plan, a 2006 initiative that aims to make streets pedestrian-friendly and viable public spaces. Using plantings, open spaces, and other design features, city planners hope to improve air quality, decrease surface runoff, and encourage residents to explore the city by foot or bike.

Portland, Oregon

Portland is an internationally recognized leader in sustainability planning, TOD, environmental stewardship, and infrastructure investments. One of the key elements of Portland's reputation for sustainability is its commitment to public transportation. For example, City-based transit ridership grew almost twice as fast as the population and three times faster than expansions in transit service between 1996 and 2006. Eighty-six percent of riders choose the region's transit system, TriMet, over driving, and transit ridership remains high throughout the week—even on weekends (Quinton, 2011a).

TriMet provides light rail, bus, and commuter rail services to the tri-county Portland region and partners with the City of Portland to deliver streetcar services. Portland's metropolitan planning organization (Metro) oversees transit at the regional level. Both authorities collaborate closely with local developers and city planners.

Since the 1970s, Portland has embraced TOD and resisted urban sprawl. City planners have encouraged dense development and tried to prevent suburban sprawl within an urban growth boundary to preserve the green space, agricultural areas, and forestland that lies beyond. Metro also provides tax incentives for TOD.

Portland's Downtown Transit Mall, established in 1978, keeps the city center pedestrian-friendly with one-way streets intended specifically for transit. Since 1975, passengers have been able to ride public transit for free—any day, any time—in downtown Portland. The free service began with certain downtown buses, the only form of transit available at the time, and is now limited to light rail and streetcar services within downtown Portland, the Rose Quarter, and the Lloyd District.

Portland also has an aerial tram that links two campuses of the Oregon Health and Science University. The aerial link, owned by the City of Portland, carries 980 people per hour in each direction; by 2007 statistics, 86.4 percent of tram riders are either employees or students of the medical facility (Quinton, 2011a).

Portland's Pearl District revitalization has become a classic case study for urban planners. In the early 1990s, the Pearl District was mostly old industrial warehouses and an abandoned rail yard. A small group of developers, along with city planners, envisioned a much denser urban neighborhood. The stakeholders worked with city government to create a comprehensive development program; the City would provide the area with a modern streetcar line, and the developers would invest in mixed-use development projects all over the neighborhoods. Collaboration between the City, private developers, TriMet, and the nonprofit Portland Streetcar has resulted in the Pearl District becoming one of Portland's most attractive neighborhoods, boasting a mix of local and national retailers, residences, and parks.

Current projects look beyond downtown Portland, aiming to link the city with other high-density communities in the region. By 2015, TriMet hopes to link Portland directly with Milwaukee, Oregon, by extending rail and streetcar services across the Willamette River. Another light rail extension, this time across the Columbia River, will connect Portland with Vancouver, Washington, by 2020. Perhaps the most comprehensive initiative, the Southwest Corridor Plan will lay out a framework for integrated transportation and land use planning along the corridor between Portland, Tigard, and Sherwood.

From green construction practices to reducing GHG emissions, congestion, and waste, TriMet has embraced a holistic environmental vision. All TriMet buses run on a biodiesel fuel blend, and the newest buses use a NASCAR-inspired engine cooling system and computer monitoring to boost fuel economy. Older buses have been retrofitted with exhaust filters that make their diesel engines burn 90 percent cleaner. Driving policies also help: At transit centers, bus drivers turn off their engines, rather than idling.

Portland maintains a strong commitment to environmental stewardship, and both it and Oregon have published climate action plans. By 2020, Oregon hopes to achieve GHG levels 10 percent lower than 1990 levels and, by 2050, 75 percent below 1990 levels. Currently, 38 percent of Oregon's carbon emissions from fossil fuels come from the transportation sector.

Trends in Local Government Sustainable Transportation Programs

When these initiatives are reviewed, a number of trends can be identified:

- **Integration of transportation planning with other services.** City or local government sustainability programs tend to focus on the whole range of city services, rather than just transportation. This is because cities, given the factors identified above (e.g., more localized and determinate economic interests, physical size, and greater integration of authority), must develop more comprehensive plans and approaches. For example, if a local government initiates a Smart Growth program that requires changes in land use and zoning, it will inevitably require coordination from water and waste management authorities, school departments, and other agencies that need to be included in coordinated land use planning.
- **Use of an integrated systems perspective.** Local and city sustainability initiatives are based on an understanding of the interaction between transportation and other social and economic systems. Naturally, this leads to a more sustainable, comprehensive view of the transportation system itself. This can be seen in a number of trends. For example, sustainable transportation initiatives emphasize that individuals plan their daily activities. It seeks to understand and influence the full array of economic and psychological factors shaping mode choice and vehicle ownership decisions in the context of these activity patterns. Similarly, sustainable initiatives try to understand and manage the relationship between infrastructure and the public institutions that operate it. It seeks to reorganize government around managing public infrastructure as an important asset whose value is maximized if it is priced, enforced, and managed effectively. Finally, it aims to better integrate transportation planning with societal needs, including opportunities for recreation and social interaction, and accessibility for children and the poor.
- **New institutional requirement.** As has been noted previously, sustainability poses a significant challenge to the ways that transportation agencies define their missions and organize their work. The transformation of local transportation agencies to managing a transportation mission within a larger decisionmaking and funding framework requires a shift in organizational culture. This has resulted in redesign of some agency structures, development of new integrated planning structures, and development of comprehensive sustainability culture change programs.
- **Funding remains a challenge.** No matter what size the community, funding is always an issue. Local and state governments have used a variety of low-cost options to encourage people to use sustainable services (e.g., use of information technology to alert commuters to train times). Major transit programs require significant new taxes (e.g., Northern Virginia's business metro tax), bond issues, or coordination with state and federal efforts. In many cases, new user fee programs have been introduced. The overriding message is that no one solution will fit all, but every program seems to need new funding initiatives. TBL would add to funding,

budgeting, and allocation challenges as funding fluidity might involve shifts into and out of transportation-oriented accounts.

In a dispersed regional/local demographic, efforts to build a sustainable culture can face special challenges in establishing consensus around program needs and resource investments. For instance, smaller rural communities may find it difficult to finance and implement transportation alternatives that are typical in urban settings (such as public transit) and they may lack the population density to make them affordable and successful. Rideshare or local employer-led bus transit has been an option in some cases. To illustrate this, the RabbitTransit System in York County, Pennsylvania, works with area employers to offer special all-day routes that serve the community's largest employer (a regional hospital) and also offers shuttle services at specific times of the day to support smaller employers. Employers pick up the bulk of the costs for these routes, but the routes are also available to the general public. As a result, RabbitTransit enjoys a diversified and sustainable revenue base.

Similarly, the public transportation system in Ottawa, Canada, OC Transpo, began offering service to rural communities in 2002, a year after 11 municipalities were amalgamated into the new City of Ottawa. Today, eight routes serve 12 smaller communities that have a total population of about 84,500. The routes operate in peak times, with some routes averaging only 35 riders per day while others serve more than 230 riders daily. OC Transpo also partners with several local bus companies and other area municipalities to offer 17 "rural partner routes." These routes connect passengers to regular OC Transpo routes or transport them directly to their destinations (e.g., the downtown area).

The low population density, along with the lack of a concentrated revenue base and the distances involved make sustainable transportation in rural areas a major challenge.

D.1.3 Federal Sustainability Programs

Federal sustainability programs are developing and expanding rapidly and derive their authority from a series of EOs (FedCenter.gov, 2012):

- **Executive Order 13423,** "Strengthening Federal Environmental, Energy, and Transportation Management" of 2007, set policy and specific goals for federal agencies to "conduct their environmental, transportation, and energy-related activities under the law in support of their respective missions in an environmentally, economically and fiscally sound, integrated, continuously improving, efficient, and sustainable manner" (Executive Office of the President, 2007)**.**
- **Executive Order 13514,** "Federal Leadership in Environmental, Energy, and Economic Performance" of 2009, enhances EO 13423 "to establish an integrated strategy toward sustainability in the federal government and to make reduction of greenhouse gas emissions a priority for federal agencies" (Executive Office of the President, 2009).

In addition, these EOs established the following processes and management tools to aid in the implementation of the sustainable practices they detail:

- Identification of a federal environmental executive
- Identification of an agency senior sustainability officer
- Establishment of the interagency Steering Committee on Federal Sustainability, which consists of the federal environmental executive and the agency senior sustainability officers
- Every federal agency was required to develop and submit to the Council on Environmental Quality (CEQ) chair and the OMB director an agency-specific strategic sustainability performance plan on June 2, 2010. This plan is also required to be updated annually.

EO 13514, Section 19, provides the following definitions applicable to this program area:

- **Agency**—an executive agency as defined in Section 105 of Title 5, United States Code, excluding the Government Accountability Office (EO 13514, Section 19(b)) (Executive Office of the President, 2009).
- **Sustainability and sustainable**—to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations of Americans (EO 13423, Section 9, and EO 13514, Section 19(l)) (Executive Office of the President, 2007). In terms of transportation, these EOs address vehicle fleet management, which includes optimizing vehicle maintenance operations, biofuels, pollution prevention tools and techniques, and used oil. Both EO 13423 and EO 13514 include goals and objectives applicable to the transportation sector. Note that EO 13514 builds upon and, in some cases, adds or amends EO 13423. The goals, objectives, and sustainable practices outlined in both EOs must be met.

In addition, Section 10 of EO 13514 requires that within 180 days of the date of this order (October 5, 2009), the U.S. DOT, in accordance with its Sustainable Partnership Agreement with the Department of Housing and Urban Development (HUD) and the EPA, and in coordination with the General Services Administration (GSA), the Department of Homeland Security, the Department of Defense (DoD), and other agencies as appropriate, shall:

- Review existing policies and practices associated with site selection for federal facilities and
- Provide recommendations to the CEQ chair regarding sustainable location strategies for consideration in sustainability plans.

In EO 13423, Section 2(d), if an agency operates a fleet of at least 20 motor vehicles, the agency, relative to agency baselines for fiscal year 2005, is required to:

- Reduce the fleet's total consumption of petroleum products by 2 percent annually through the end of fiscal year 2015 (EO 13514, Section 2(a)(iii)(C), changed this date to 2020);
- Increase the total fuel consumption that is nonpetroleum based by 10 percent annually; and
- Use plugin hybrid (PIH) vehicles when PIH vehicles are commercially available at a cost reasonably comparable, on the basis of life-cycle cost, to non-PIH vehicles.

In regard to energy-related issues, EO 13423, Section 3(a), mandates that the heads of each agency implement within the agency sustainable practices for vehicle fleet management. EO 13514, Section 2(a)(iii), further requires a reduction of GHG emissions from a reduction in the use of fossil fuels by:

- Using low-GHG-emitting vehicles including alternative fuel vehicles and
- Optimizing the number of vehicles in the agency fleet.

Section 12 of EO 13514 requires the Department of Energy (DOE), in coordination with the GSA, to issue comprehensive guidance on federal fleet management. In April 2010, DOE's Federal Energy Management Program (FEMP) issued "Guidance for Federal Agencies on EO 13514 Section 12, 'Federal Fleet Management,'" which fulfills this Section 12 requirement. This guidance, accompanied by the DOE *Comprehensive Federal Fleet Management Handbook*, helps federal fleet managers implement federal fleet requirements.

As can be seen, federal efforts are focused largely at increasing the sustainability of the operations of the federal government using a compliance-based approach. This is supported by a wide range of federal programs that attempt to assist communities, states, and the private sector in developing sustainability programs. Table D-12 shows major sustainability assistance programs by agency; these programs cover a broad range of services and goals.

Table D-12. Sample federal sustainability programs by agency.

Agency	Program Description
HUD	The **Sustainable Communities Initiative** has four components: • Sustainable Communities Planning Grants • Sustainable Communities Challenge Grants • Creation of a Capacity Building Program and Tools Clearinghouse • Joint HUD–DOT–EPA Research Effort on Transportation and Housing Linkages **Catalytic Investment Competition Grants.** This program is a part of the Community Development Block Grant, but like the Sustainable Communities Initiatives, the funding is competitive and not formula based. The funding is specifically designed to leverage other funds, including Choice Neighborhoods and Sustainable Communities grants. Four programmatic eligibilities were outlined: (1) reclaim vacant property and create green infrastructure; (2) remove property-related obstacles to recovery; (3) facilitate economic development and neighborhood vitality in targeted neighborhoods; and (4) support TOD. **Choice Neighborhoods.** The intention of the program is to create a grant program focused broadly on distressed neighborhoods with a strong emphasis on community planning for school and educational improvements as part of neighborhood revitalization.
DOT	**Livable Communities Program.** This funding supports three separate initiatives that are each part of DOT's role in the interagency Partnership for Sustainable Communities. Projects include (1) $307 million in transit funding to increase the planning and project development capabilities of local communities. The program assists transit agencies in using the Job Access and Reverse Commute formula grants; Alternatives Analysis grants; and formula grants for state and metropolitan planning to support planning for and implementation of livable and place-based investments in transportation. (2) $200 million in highway funding for a competitive livability grant program to assist states and local governments in integrating planning processes within transportation, land use, and natural resource conservation. Grants could also be used to enhance the capacity to plan, implement, and assess transportation projects according to livability goals and investment performance objectives. The funds could be used to improve modeling and data collection. (3) Establishment of an Office of Livable Communities in the Office of the Secretary to coordinate multimodal and interagency livability efforts and lead DOT's investment decisions that focus on livable communities. **Transportation Infrastructure Finance and Innovation Act (TIFIA) funding.** Provides loans and grants (as well as supporting public–private partnerships) on the basis of sustainability for "projects of regional or national significance." This encourages sustainability-driven strategies in transportation. **INVEST** (Infrastructure Voluntary Evaluation Sustainability Tool) is a tool developed by the FHWA to be used by state and local transportation agencies to assess the sustainability of road and highway projects. The tool rates projects in terms of economic, environmental, and social factors. **Transportation Investment Generating Economic Recovery (TIGER) grants funded in American Recovery and Investment Act (ARRA).** The U.S. DOT has awarded grants under three programs to surface transportation projects that will have a significant impact on the nation, a metropolitan area, or a region. The TIGER Discretionary Grant program provides a unique opportunity for the U.S. DOT to invest in road, rail, transit, and port projects that promise to achieve critical national objectives. Congress dedicated $1.5 billion for TIGER I, $600 million for TIGER II, and $526.944 million for the FY 2011 round of TIGER grants to fund projects that have a significant impact on the nation, a region, or a metropolitan area. TIGER's highly competitive process, galvanized by tremendous applicant interest, allowed DOT to

Table D-12. (Continued).

Agency	Program Description
	fund 51 innovative capital projects in TIGER I and an additional 42 capital projects in TIGER II. TIGER II also featured a new Planning Grant category, and 33 planning projects were also funded through TIGER II. In the FY 2011 round of TIGER grants, DOT awarded 46 capital projects in 33 states and Puerto Rico. Each project is multimodal, multijurisdictional, or otherwise challenging to fund through existing programs. The TIGER program enables DOT to use a rigorous process to select projects with exceptional benefits, explore ways to deliver projects faster and save on construction costs, and make investments in the nation's infrastructure that make communities more livable and sustainable. **FHWA Planning and Environment Linkages (PEL) initiative** is an approach to transportation decisionmaking that considers environmental, community, and economic goals early in the planning stage and carries decisions through development, design, construction, and maintenance. By promoting greater communication within and among transportation and resource agencies, PEL can help them to simplify decisionmaking and project development. Developed by a team of representatives from the FHWA and seven other federal agencies, **Eco-Logical** articulates a vision for an infrastructure development process that endorses ecosystem-based mitigation through integrating plans and data across agency and disciplinary boundaries. The FHWA's Eco-Logical grant program supports the initiatives that implement the principles set forth in Eco-Logical. Currently, the grant program funds 15 projects nationwide.
DOE	For more than a decade **NREL** has represented the spirit of the EO intent for DOE operations to support and enhance TBL sustainability. As would be expected, numerous initiatives focus on a host of conservation, renewable energy, environmental improvement, and other resource management initiatives for lab and other facility operations. The transportation-related initiatives focus on both alternative fuels and fuel conservation through trip-reduction approaches.
EPA	**Healthy Communities Initiative.** EPA consolidated several new and existing programs into the Healthy Communities Initiative. All program areas are grant programs and managed by EPA's Smart Growth office.

Additional sustainability initiatives, programs, and tools that have a more limited focus include the following (FedCenter.gov, 2012):

- **Building for Environmental and Economic Sustainability (BEES).** BEES 4.0 software is now available for downloading at no charge. BEES is a powerful technique for selecting cost-effective, environmentally preferable building products. BEES reduces complex, science-based technical content (e.g., more than 400 environmental flows from raw material acquisition through product disposal) to decision-enabling results and delivers them in a visually intuitive graphical format.
- **Chartered Institution of Building Service Engineers (CIBSE) Sustainability Tool.** This tool is a searchable, online database of best practice sustainability measures for building services engineers. The measures are a distillation of well-established sustainability guidance. The tool provides a short list of measures for specific sustainability topics and references to further guidance, including the section of the relevant document. Issues addressed include water use, adapting buildings for climate change, sustainable drainage systems, site ecology and habitats, and energy recovery. This is not a comprehensive list of all issues addressed.

- **Earth 911 Reuse and Recycling Services.** This program helps users identify available recycling services in their state and city for items such as plastics (e.g., packaging peanuts, bags, containers); paper (e.g., books, newspaper, drink boxes, chipboard, cartons); paint products; organic material (e.g., brush, grass clippings, tree trimmings, weeds, soil); metal (e.g., aerosol cans, vehicles, appliances, cans, foil, hangers, propane tanks); glass; batteries (e.g., vehicle, NiCad, rechargeable); construction and demolition materials (e.g., asphalt, flooring, ceiling tiles, carpet padding, concrete, windows, stone, linoleum, porcelain products, brick); and miscellaneous items, such as mattresses, furniture, cooking oils/grease, fluorescent bulbs, and medical equipment.
- **EPA's Regional Vulnerability Assessment (ReVA) program.** The ReVA program focuses on region-scale integrated assessment with the aim of assisting decisionmakers in identifying and locating both environmental resources and the conditions that are stressing those resources.
- **GHG impact tools.** EPA and its partners have developed several tools to help individuals and organizations determine the GHG impact of their purchasing, manufacturing, and waste management actions. The Recycled Content (ReCon) tool is used to estimate the life-cycle GHG and energy impacts of purchasing or manufacturing certain materials. Waste Reduction Model (WARM) assists solid waste managers in determining the GHG impacts of their waste management practices. Durable Goods Calculator (DGC) aids in making informed decisions regarding the GHG and energy impact caused by the disposal of durable household goods. Finally, the GHG Equivalencies Calculator expresses quantities of GHG emissions in terms of metrics, such as number of cars, gallons of gasoline, and acres of forest.
- **GSA Sustainable Facilities Tool.** The Sustainable Facilities Tool is a one-stop online resource to support decisionmaking regarding sustainable building principles, materials, and systems. Targeted to help project personnel identify and prioritize cost-effective, sustainable strategies for small projects that do not normally engage workplace consultants or designers, this tool helps users understand and select environmentally preferable solutions for renovations, alterations, and leases.
- **Improving Air Quality in Your Community.** This website features activities for reducing both indoor and outdoor pollution, including diesel engine retrofit programs, improving air quality in local schools, and pollution prevention options for small businesses. These projects have a successful track record: They were enacted previously by state and local governments across the country. This site includes information about the costs to establish and maintain each project and how local communities can apply for EPA grants to kick-start their activities.
- **Pharos Initiative.** Sponsored by the Healthy Building Network and its partners, this tool seeks to define a consumer-driven vision of truly green building materials and how they should be evaluated in harmony with principles of environmental health and justice. Pharos evaluates materials across several impact categories, such as energy/water usage, air quality impact, and toxicity, but also introduces new categories, such as occupational safety, social justice, and habitat impact that, to date, have not been included in any material rating system. Another Pharos tool, PharosWiki, provides users a place to research materials, chemicals, and building products as well as share their experience and knowledge.
- **READ-Database.** This tool provides GIS data and is available online to help renewable energy developers identify appropriate sites for renewable projects, such as utility-scale wind, solar, and geothermal energy facilities that are unlikely to interfere with military activities and training and have the fewest environmental conflicts. This database was developed by the Natural Resources Defense Council (NRDC) in coordination with the DoD to help eliminate conflicts between renewable energy developments and DoD operations.

- **Smart Growth Policies Database.** The policies in this database represent a variety of approaches ranging from formal legislative or regulatory efforts to informal approaches, plans, and programs. These actions represent real and innovative ways for communities to realize Smart Growth.
- **Sustainable Management Approaches and Revitalization Tools-electronic (SMARTe).** SMARTe 2007 is a web-based, menu-driven decision analysis support system for developing and evaluating future reuse scenarios for potentially contaminated land. SMARTe contains guidance and analysis tools for addressing all aspects of the revitalization process, including planning, environmental, economic, and social concerns. SMARTe is intended for all revitalization stakeholders. SMARTe is being developed by EPA's Office of Brownfields Cleanup and Redevelopment and Office of Research and Development, with support from the Interstate Technology and Regulatory Council.
- **Sustainable Water Infrastructure.** This website provides information about various initiatives to promote sustainable infrastructure. Specifically, it addresses the four pillars of sustainable infrastructure: better management, full-cost pricing, efficient water use, and watershed approaches to protection.

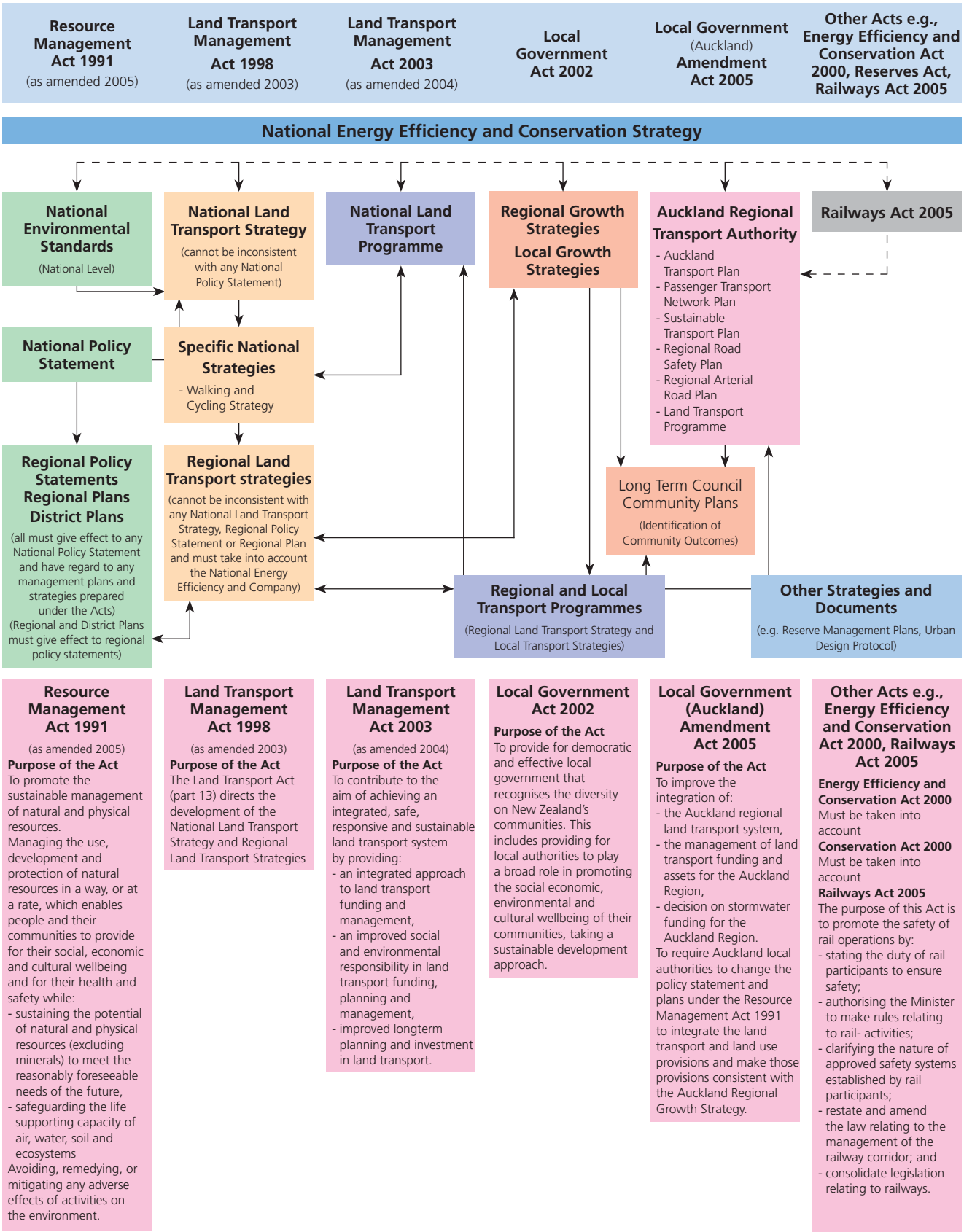
D.1.4 Sustainability and Sustainable Transportation Programs and Policies in Other Countries

A number of other countries have developed advanced sustainability and sustainable transportation programs and policies. Although differences in institutional relationships, political systems, and economic, demographic, and land use patterns limit the value of international comparisons, they nevertheless demonstrate potential techniques or approaches that could be adapted to U.S. context.

For example, New Zealand, widely regarded as a sustainable transportation leader, is at the forefront in developing a coordinated national policy for sustainability. The 2008 New Zealand Transport Strategy (NZTS) integrated transportation and climate change into a single sustainability program. Sustainability is explicitly part of its future vision: "People and freight in New Zealand will have access to an affordable, integrated, safe, responsive, and sustainable transport system." The plan's targets reflect the stated vision and include halving per capita GHG emissions from domestic transport by 2040, increasing rail's share of freight to 25 percent of ton-kilometers by 2040, and using electric vehicles widely. While setting targets is not necessarily unique for transportation plans, NZTS 2008 is set apart because the targets are statutorily enforced through the Government Policy Statement on Land Transport Funding, which establishes short-term system goals that will be achieved by prioritizing funding over the next 6 to 10 years. In addition to the statutory funding statement, NZTS will also be evaluated through a Transport Monitoring Indicator Framework, which is being made available to the public via an online interactive version. The framework provides a procedure to monitor progress toward the objectives, sector outcomes, and targets in the Transport Strategy and Government Policy Statement. It provides a tool for evaluating the effectiveness of the current policy and for guiding future decisions. Last but not least, it also provides accountability (Georgia Tech Research Corporation, 2011).

New Zealand's sustainable transportation program builds on a long history of increasing sustainability initiatives in government, as depicted in Figure D-4. In New Zealand, as it is with many state governments in the United States, successful sustainability programs take a decade or two to achieve and require substantial consensus building and careful development.

One of the striking elements of New Zealand's sustainability efforts has been the emphasis on developing a business case for sustainability. This business case has focused on both formal ROI estimates and qualitative stories that convey clearly the benefits of sustainability. For example,



Source: Auckland Regional Transport Authority (2006).

Figure D-4. Overview of New Zealand's sustainability legislation and programs.

the Auckland Regional Land Transport Strategy sets out seven objectives for transport in Auckland for 2006–2016. The first five objectives incorporate the national transport objectives; the last two objectives focus on Auckland and include an economic efficiency dimension (Auckland Regional Transport Authority, 2006):

1. Assisting economic development
2. Assisting safety and personal security
3. Improving access and mobility
4. Protecting and promoting public health
5. Ensuring environmental sustainability
6. Supporting the Auckland Regional Growth Strategy
7. Achieving economic efficiency

The program established monetized targets for each goal, a methodology to estimate the benefits, and a series of indicators that could be used to track achievement of goals (and convert performance into monetized benefits). Collectively, this program creates a compelling business case for sustainability. Table D-13 summarizes these targets.

Using this approach, Auckland was able to develop a compelling business case for its sustainability plan. Specifically, Auckland was able to show that for an annual allocation of 4 percent of total transportation spending (around NZ$42 million), the sustainability plan was anticipated to yield an annual benefit of NZ$90 million.

The United Kingdom is another leader in sustainability planning and sustainable transportation. The most compelling points of its initiatives are the emphasis on prioritization in transportation and the integration of planning and implementation at all levels of government.

The prioritization emphasis resulted from the 2008 economic crash, which forced severe budget cuts and restrained spending. Critical to the development of this policy was the Eddington Transport Study. Led by Sir Rod Eddington, it was commissioned by the British government to document the impact of transport decisions on the economy and the environment. The Eddington study confirmed the link between transport and the economy but focused on congested and growing cities, as well as interurban links and international gateways where congestion is a major threat to economic growth. Critically, Eddington emphasized the need to make choices and to balance sustainability with economic growth. The basis of this approach was to state the goal or purpose of a specific transportation policy and to relate it to broader societal goals. Building a road became not simply a way of transporting goods and people from point A to point B, but part of a larger government mission coordinated with other social missions. Figure D-5 shows this logic.

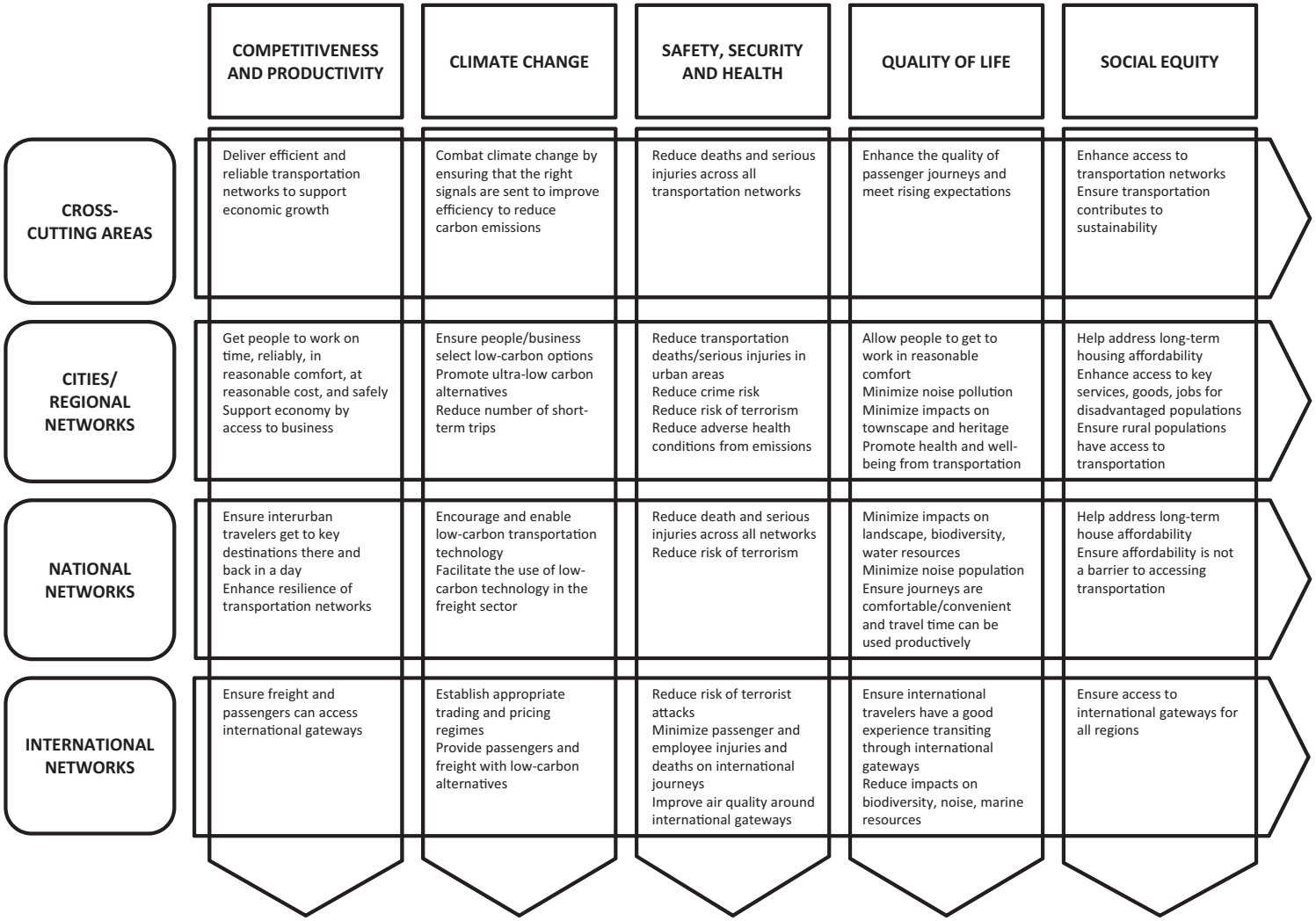
Table D-13. Auckland regional land transportation monetized benefit targets.

Objective	Monetized Benefit*	Relevance to TBL Element		
		Economy	Environ.	Society
Assisting economic development	NZ$50M	●		●
Assisting safety and personal security	NZ$31M			●
Improving access and mobility **	NA	●		●
Protecting and promoting public health	NZ$5M			●
Ensuring environmental sustainability	NZ$4.4M		●	
Supporting the Auckland Regional Growth Strategy**	NA	●	●	●

* NZ$ = New Zealand Dollars

** Cannot be quantified

Source: Auckland Regional Transport Authority (2006).



Source: Adapted from (UK) Department for Transport (2007).

Figure D-5. Integration of UK government transportation goals across different modes, levels of government, and goals.

The Eddington study also concluded that transportation planning focused prematurely on developing and delivering a specific scheme or solution when it should look at a wide range of possible actions, not just at investment in infrastructure. Critically, both the study and government policy require that national, regional, and local programs be aligned within a broader policy context to understand the goal and purpose of transportation investments. When these decisionmaking processes are aligned, it is possible to compare the merits of different road- and rail-based solutions to interurban congestion problems and to prioritize funding among the programs. This changes the way government engages with stakeholders and emphasizes the need to build consensus on future transportation needs. Putting proposals through this rigorous process enables more secure government funding for the projects. It contrasts with current programs, where individual projects are considered individually and subject to late adjustments in timing (or even cancellation) as better propositions emerge. This leads to inefficiency and disappointed expectations that might have been avoided by a more coordinated approach [(UK) Department for Transport, 2007].

From a state or regional point of view, the British approach shows how multiple transportation modes, agencies, and goals can be combined to create a plan that gives government leaders a common tool to analyze project costs and benefits. Individual interests and stakeholder pressures still affect outcomes, but now decisionmakers can identify projects that meet major policy goals, understand their impact on policy areas, and identify tradeoffs.

D.1.5 Other Tool-Related Findings from the Research

In the course of the research, the following citizen engagement tools, feedback and communication tools, and lessons learned from international experience were identified.

Citizen Engagement Tools

Specific tools that have been used to involve citizens in decisionmaking include the following:

- The Service First Unit of the United Kingdom's Cabinet Office commissioned the creation of a People's Panel. The panel consists of 5,000 members of the public randomly selected from across the United Kingdom. It was designed to represent a cross section of the population (e.g., age, background, and region). Panel members are consulted on how public services are delivered and how that delivery can be improved from the user's point of view. The panel provides a bank of individuals who can be used for a wide range of research and consultation. In addition, data is kept on past interactions so the Service First Unit can track change over time.
- The Netherlands has been experimenting with a number of participatory democracy innovations with the direct goal of reducing legal objections to development projects. For example, the municipality of Hoogeveen has implemented the "Forge" approach to city planning (the metaphor being a forge is a workshop where new tools are made). This approach is a dramatic attempt to push control of planning and needs assessments to citizens. All citizens can participate in a Forge, where they come forward with direct ideas and recommendations for projects. Interactive citizen groups then debate and discuss priorities on various "Forge nights," gradually developing budget priorities before voting on budgets on "budget nights." So far, more than 18 Forges are operational, and they are generally seen as successful (van Hamersveld and Bina, 2008).
- The United Kingdom's e-petition program allows citizens to create their own petition or join petition efforts online. Once a petition has reached 100,000 signatures, the issue is automatically debated in the national Parliament.
- The Brazilian city of Porto Alegre—a city of 1.5 million with an economic sphere of more than 4 million people—has been using a system of participatory budgeting since 1989. Under this system, every January a series of assemblies convene across the city and receive instruction

from city specialists in technical and system aspects of city budgeting. Each assembly then discusses its goals and needs. When consensus is reached, neighborhood assemblies are rolled up into larger plenary assemblies in each of the city's 16 districts. In addition, special assemblies deal with such areas as transportation, health, education, sports, and economic development. These large meetings (participation can reach more than 1,000) elect delegates to represent specific neighborhoods. The mayor and staff attend to respond to citizen concerns. In the following months, delegates meet weekly or biweekly in each district to review technical project criteria and district needs. City department staff may participate according to their area of expertise. At a second regional plenary, regional delegates prioritize the district's demands and elect 42 councilors representing all districts and thematic areas to serve on the Municipal Council of the Budget. The main function of the Municipal Council of the Budget is to reconcile the demands of each district with available resources and propose and approve an overall municipal budget. The resulting budget is binding; the city council can suggest but not require changes. Only the mayor may veto the budget or remand it back to the Municipal Council of the Budget (a veto or remand scenario has never occurred). A 2003 World Bank paper suggested that participatory budgeting has led to direct improvements in facilities in Porto Alegre (Wagle and Shah, 2003). As a result of Porto Alegre's experience, about 140 of Brazil's cities (about 2.5 percent) have adopted participatory budgeting.

These and other examples cited throughout this report suggest that there are numerous ways to integrate greater public participation into decisionmaking without losing technical excellence or imposing excessive delay.

Feedback and Communication Tools

Another critical principle in preparing organizations for sustainability changes is the need to design all policy instruments with explicit feedback and communication mechanisms. A European-wide review of transportation policy identified eight different types of outputs (i.e., program actions and impacts) and feedback (essential cause-and-effect loops) from different countries' transportation agencies at national, state/regional, and local levels. The study also identified key factors that can enable transportation agencies to correctly identify cause–effect factors and probable policymaking effects. The factors include the following:

- Broad-based stakeholder participation throughout the policy development and implementation process, especially in the initial scoping and design of the policy intervention
- Established mechanisms for interagency and intergovernmental (i.e., national–local, national–state/regional, state/regional–local, local–local, state/regional–state/regional) communication and coordination
- A deep body of technical experts on all dimensions of the proposed policy and the involvement of these experts at all stages of the policy process
- Experienced administrators that understood how the policy would be implemented and present at all stages of the policymaking and implementation process
- Multiple feedback loops combined with an active performance/implementation metrics measurement program
- Transparent processes and honest recognition of challenges and opportunities
- Flexible implementation and management strategies
- Feedback and the reinforcing elements of measurement and communications

These factors are the general principles that transportation agencies need to adopt to face an uncertain, rapidly changing future. Section 6.2 of the main report discusses specific actions and policies that agencies could undertake in detail under different scenarios. In analyzing these policies, the research team noted a general phenomenon: No matter what the scenario, certain

policies, actions, programs, and concepts made sense. As a result, these generalizable optimal actions are preferable over actions of limited value.

Lessons Learned from International Experiences

The examples cited above contain many interesting lessons for U.S. transportation agencies. For example, the general tendency toward more centralized and coordinated government structures has been important to their ability to develop more comprehensive sustainability planning (e.g., the United Kingdom, the Netherlands, and New Zealand). The flexibility and overall executive control in these countries have made it relatively easy to reorganize and reshuffle agencies and departments to create more integrated transportation TBL-based public sector organizations. For example, in the United Kingdom there have been more than 30 major reorganizations of national government departments and agencies (which have split up, merged, or eliminated major government departments) between 1979 and 2009. Of these, many were made with little external consultation or legislative oversight and were designed and implemented within an extremely rapid time frame. For example, the Department for Energy and Climate Change in the United Kingdom was created by merging elements of the Business, Innovation, and Skills Department with the Department of Environment, Food, and Rural Affairs (themselves both the product of multiple reorganizations). The decision to create the new department and the development for this new organization's design was accomplished in one evening. No legislative approval was needed prior to the reorganization, and the new department came into being with no notice between the end of one working day and the beginning of the next [See White and Dunleavy (2010)]. The point of the discussion is that agencies with broad powers to implement top-level strategy (not limited in focus on a single bottom line or public utility) can react quickly to shifting policy systems.

However, it is noticeable that even in countries with a high degree of institutional flexibility and control, new planning mechanisms and major cultural change have to occur to successfully manage the new system. In each country, despite the existence of many more integrated, sustainability-focused organizations, there are still the same battles between interest groups, organization interests, and different constituencies. In fact, of the clearest findings from our analysis of international initiatives, the extent to which they have made any real difference is unknown. Evaluation of the impacts of international sustainability programs are lacking and, to date, there is very little objective analysis of whether investment in these programs has led to any significant change that could not have been achieved by the previous organizations or would not have occurred due to broader social and economic change.

D.2 Key Insights

The literature review and stakeholder interviews revealed a number of key insights:

- **Sustainability is a complex, challenging idea.** There is growing understanding of the meaning of sustainability, but generally the term is not well understood. Its inherent complexity and ambiguity deters decisionmakers, and key stakeholders and interest groups are often reluctant to embrace the concept and uncomfortable with its connotations.
- **Understanding of and support for sustainability is increasing.** Despite certain resistance toward sustainability, its acceptance is growing, as evidenced by more sustainability programs and greater integration of sustainability into transportation policy and all levels of government.
- **TBL needs a fiscal element.** TBL is gaining acceptance, too, but many believe it requires a fourth element—fiscal sustainability. Economically struggling states are more focused on system preservation, rather than new capital programs. Now, programs must consider long-term

funding and support. This means sufficient and dependably reliable funding is needed to provide for the longer view that TBL requires. Innovations, such as FCA or LCC, should capture the full cost of transportation investments and demonstrate how they will be funded in the future.

- **Social indicators are difficult to develop.** Many states and localities are developing sustainability indicator programs. These programs tend to have relatively robust indicators of economic and environmental progress; however, it is difficult to develop social indicators. Most programs tend to use census data to develop environmental equity programs, but there is a need to develop more comprehensive social indicators. States that have attempted to do this have found costs prohibitive, measures difficult to develop, and data hard to obtain.
- **Waiting for demand versus developing demand.** A number of interviewees stated that sustainability had to wait for strong leadership from the state or local leaders, or from the public as a whole. Others said that support for sustainability could be generated slowly by small modifications to the planning process and indicator system, and by transportation agencies developing a constituency for sustainability. Both positions have their merits. However, cities such as Portland, Oregon, show that small-scale efforts can generate public demand for sustainability.
- **Sustainability can't be an add-on; it must inform organizational culture and internal process.** The literature review and practitioner interviews suggest that sustainability must be a complete process. Transportation agencies need to change their processes, culture, and operations to best support sustainability. This requires developing a new vocabulary and set of processes to understand sustainability and place it in the context of traditional transportation engineering. In addition, it requires recruiting new specialists with different expertise, changing individual performance standards to influence behavior, encouraging culture change, and developing new internal processes (e.g., transportation modeling) and organizations.
- **One size will not fit all.** The literature and practitioner interviews both emphasize that one size will not fit all when it comes to sustainability programs. The unique conditions of each state require unique solutions, and there are a range of tools and innovations to meet these needs. For example, most states have adopted similar performance standards and methods, so combining different indicators could prove useful, as would scenario planning.
- **The business case for sustainability needs to be built and ROI shown.** Interviewees and the literature both conveyed the need for a comprehensive business case for sustainability that shows clearly the ROI for sustainability expressed in monetary or monetary-equivalent terms. The ROI should include the full range of societal, economic, and environmental elements of sustainability. Several such tools exist [e.g., Parsons Brinckerhoff's PRISM™, HDR's sustainability ROI (SROI)] but no such tool has gained wide acceptance in the United States.
- **Localities are the leaders in sustainability.** TBL sustainability initiatives can most readily be pursued on a local level, as significant progress and focus can be seen in a number of cities and localities. Localities have the authority (e.g., control over land use), underlying resources (e.g., transit systems, concentrated populations), and revenue sources (e.g., user fees, local taxes) to support some TBL sustainability programs. TBL consensus-building challenges are increasingly complex on a state, regional, and national scale. Ultimately, to succeed, TBL sustainability must be embraced at all levels of government and across economic and societal sectors.
- **Sustainability requires public and stakeholder engagement.** The literature emphasizes that successful sustainability programs need to be based on substantial stakeholder buy-in and constant public involvement. The vast changes required by sustainability require planning and implementation to go beyond the old traditional, limited public involvement process.

Instead of relying on traditional approaches, several sustainability initiatives have adopted a more direct and participatory form of public engagement to achieve a workable consensus on needs and goals. Several transportation agencies have successfully engaged the public and

organized interests in forums where decisions on needs and goals are genuinely up for discussion rather than being pushed through with Q&A and minimal debate. Some transportation policy analysts have suggested that transportation planners should be better trained and effective as facilitators of stakeholder debates and discussions rather than simply as managers and collectors of citizen input (Forester, 1989; Innes, 1995).

In this regard, Arnstein's "ladder of citizen participation" is useful (Arnstein, 1969). As Figure D-6 shows, Arnstein visualized eight levels of citizen participation. The top three rungs represent real citizen participation and control, and the bottom five represent increasing control and management of citizens' needs and goals. Planners have traditionally resisted citizen involvement on the grounds that citizens lack the expertise to participate in technical discussion. However, perceptions of failure of central planning and process-driven public involvement, coupled with continued expansion of economic and demographic information available to citizen groups and organized interests, will increase demand for change to traditional transportation decisionmaking. This need to involve the public more directly in decisionmaking to attain support for future initiatives suggests that transportation agencies must develop new mechanisms to bring the public into the process.

Transportation agencies could include the public throughout the planning process via small meetings with stakeholders, larger visioning events, or website surveys and could engage stakeholders and community members on what sustainability initiatives are important to them. For example, Newark's Green Future Summit in 2007 was attended by local and national experts to facilitate a process to enable the people of Newark to define what sustainability means to Newark and the overarching goals for making Newark a more sustainable place to live and work. The City of Newark intends to use a report from the summit as a starting point for the development of its sustainability plan. Once this is completed the public can continue to be involved in the development of specific metrics for a sustainability plan.

In another case, PlaNYC contains 127 initiatives aimed at achieving the City's 10 sustainability goals. PlaNYC contains a matrix of initiatives and goals and the implementation plan matrix that are used day-to-day to manage and coordinate the plan. The public and stakeholders were informed of the plan with substantial public input—as it was developed and as key metrics were chosen. New York releases a PlaNYC Progress Report to the public each year with detailed updates on progress toward the 10 sustainability goals.

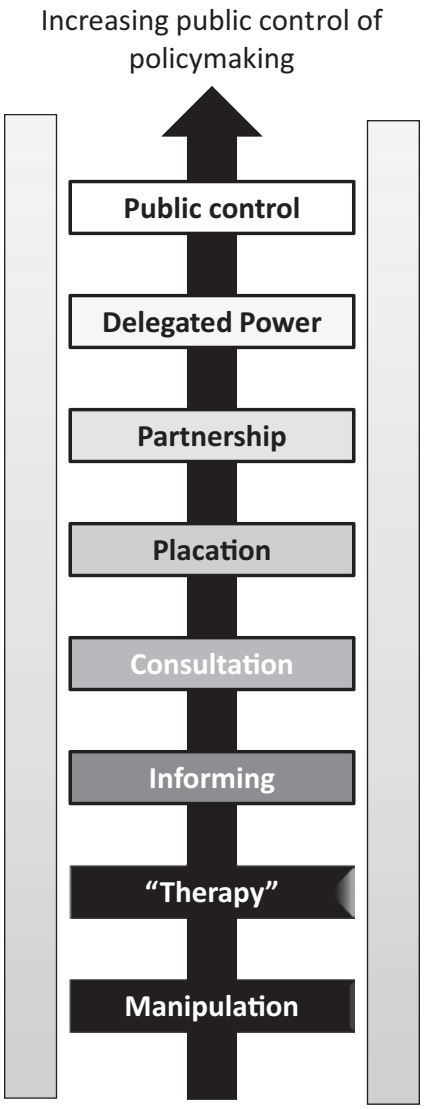


Figure D-6. Levels of public participation.

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APPENDIX E

Subject Matter Experts Interviewed

Organization	Office/Title
Federal	
Environmental Protection Agency (EPA)	Director, Office of Policy, *Former* NCHRP 20-83(7) Panel Member
U.S. DOT Federal Highway Administration (FHWA)	Office of Environment and Planning
USDA National Park Service	USDA Forest Service, NCHRP 20-83(7) Panel Member
State DOTs	
Alabama DOT	Assistant Chief Engineer for Policy and Planning, NCHRP 20-83(7) Panel Member
California Air Resource Board	Chief, Air Quality and Transportation Planning Branch
Caltrans	Division of Transportation Planning
Colorado DOT	Environmental Planner, NCHRP 20-83(7) Panel Member
Delaware DOT	Planning Director
Florida DOT	Chief Engineer
Maryland DOT	Office of Freight and Multimodalism—Project Manager Transportation Planning, Deputy Director Transportation Planning, Assistant Deputy Director
Maryland State Highway Administration	Special Assistant to the Director of Planning, NCHRP 20-83(7) Panel Member Director, Transportation Planning
NYSDOT	Policy and Planning Division, Statewide Policy Bureau, NCHRP 20-83(7) Panel Member GreenLITES Project Manager, Policy and Planning Division Special Assistant for Environmental Concerns to the Operations Division Environmental Analysis Bureau
Virginia DOT	Chief of System Operations Administrator, Transportation and Mobility Planning Chief Engineer for Program Development Chief of Policy and Environment
Washington DOT	Director of Strategic Assessment, NCHRP 20-83(7) Panel Member
Regional, MPOs, and Local Agencies	
Contra Costa Transportation Authority	Executive Director Planning Director
Delaware Valley Regional Planning Commission (DVRPC)	Director of Planning Assistant Manager of Special Projects

Organization	Office/Title
Research Organizations, Academics	
Hillsboro County MPO	Executive Director Transportation Planning and Program Group Leader
Metropolitan Area Planning Council (Boston)	Manager of Transportation Group
Port Authority New York and New Jersey	Sustainability Director (Engineering), Office of Policy, Aeronautical Technical Services Transportation Department Supervisor, Environmental Programs, Aviation Department
SANDAG	Planning Director
Modes	
Port of Long Beach	Director of Planning
American Transportation Research Institute	Vice President of Research
RAND	Senior Fellow, Former Director of Transportation
Rutgers University	Professor and Director of Voorhees Transportation Center
Texas Transportation Institute	Principal Investigator, 08-74, Sustainability Performance Measures for State DOTs and other Transportation Agencies
Urban Land Institute	Managing Director for Infrastructure
University of Massachusetts at Amherst	Director, Transportation Center, Civil and Environmental Engineering Department
Victoria Transportation Policy Institute	Executive Director
Practitioners and Consultants	
Booz Allen	Sustainability Project for USDA
Booz Allen	Booz Allen's Response to Executive Order 13514, Sustainability for Federal Agencies
Booz Allen	Transit Sustainability
CH2MHill	Formerly Florida DOT
Independent Consultants	Former Secretary Louisiana DOT, Rhode Island DOT, NJ Office of Policy Former Contractor to Urban Land Institute Independent Transportation Environmental Management Consultant; Former Environmental Quality Bureau Director, Pennsylvania DOT; Consultant to AASHTO Center for Environmental Excellence Former Director of Center for Advanced Transportation Technologies (CATT) Laboratory at University of Maryland
Parsons	Director of Sustainable Development, NCHRP 20-83(7) Panel Member
Parsons Brinckerhoff	Markey Leader, Transportation Sustainability, NCHRP 20-83(7) Panel Member

APPENDIX F

TBL Maturity Assessment Tool

This assessment tool was developed as part of NCHRP Project 20-83(7), "Sustainable Transportation Systems and Sustainability as an Organizing Principle for Transportation Agencies." The tool is in the form of a self-administered survey to help transportation agencies assess their maturity and progress toward supporting a triple-bottom-line (TBL) sustainability policy system. It is based on a generalized sustainability maturity model developed as part of this project. This model is shown in Figure F-1.

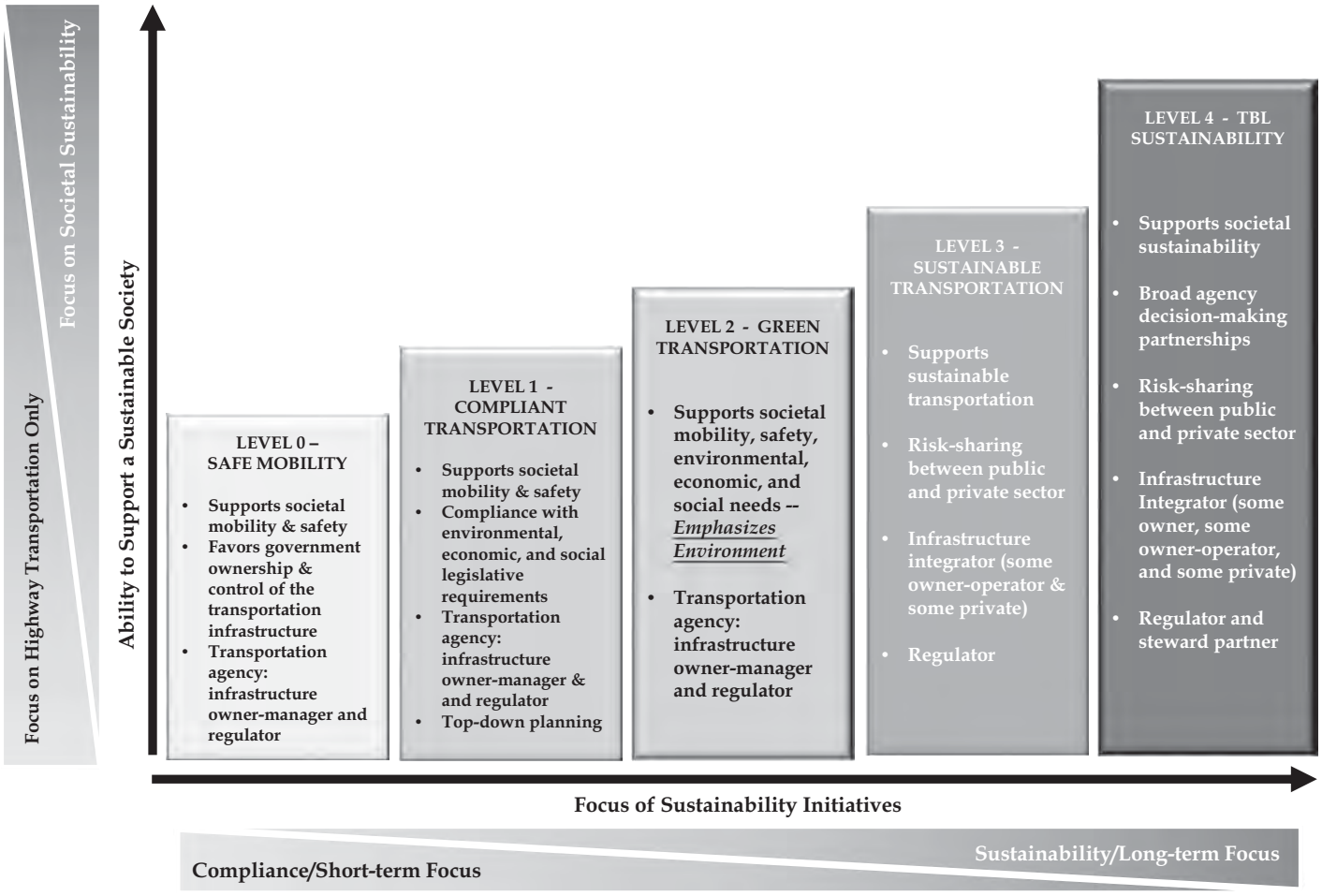

Figure F-1. Sustainability—maturity concept agency view.

This tool is an advisory, heuristic device only.

- *It is intended to encourage discussion and help agencies understand their current position and potential actions that they could take to achieve a high level of maturity vis-à-vis sustainability.*
- *It does not assess the degree to which policies support sustainability. Rather it assesses the maturity of agency structure and business culture related to their ability to support evolving sustainability policy systems.*

The assessment follows a number of basic functional dimensions to characterize an agency along a sustainability maturity scale—based on a vision of how an agency is likely to function under a TBL sustainability policy system. The basic functional dimensions are:

A. Developing Consensus on Needs

B. Planning and Programming

C. Budgeting and Resource Allocation

D. Rulemaking and Regulation

E. Service and Project Delivery

F. Compliance and Dispute Resolution

G. Education and Cultural Development

H. Outreach and Communications (to Public and Stakeholders)

F.1 Instructions

Users should review each of the following tables and select a single set of characteristics that best describe the agency. Users can:

- Combine scores to find an overall maturity rating,
- Compare scores for each dimension to focus on "trailing" functions,
- Judge what is most likely to change under a TBL policy system, and
- Evaluate potential initiatives the agency might take to advance in any functional area.

A. **CONSENSUS ON NEEDS AND GOALS:** Processes by which transportation policy systems identify needs, gaps, and requirements; build consensus around a prioritized ranking of potential needs; and develop acceptable goals and priorities for transportation.		
QUESTION: Are the needs and goals assessment functions in this agency best characterized by:		
SCORE	**STATEMENT**	**YES/NO**
1	• Needs driven by political decisionmakers and major stakeholders • Strategic goals determined by high-level decisionmakers and constrained by funding and regulations (including environmental) • Public participation limited to formal regulated processes	
2	• Needs driven by political decisionmakers and major stakeholders • Strategic goals determined by high-level decisionmakers and constrained by funding and greater focus on regulatory compliance (including environmental) • Some outreach and public consensus building	
3	• Needs driven by political decisionmakers, major stakeholders, and assessment of public sentiment • Greater focus on environmental improvement, stewardship, and social context • Significant formal outreach and consensus-building efforts	
4	• Needs more driven by public sentiment, performance, and sustainability considerations • Goals focus on sustainable transportation services and programs • More transparency and active outreach and two-way public dialogue	
5	• Cross-agency decisionmakers, stakeholders, and the public participate actively in needs determination and goal-setting • Goals and policies focused on TBL sustainability • Active two-way public engagement and consensus in strategic decisions	

B. PLANNING AND PROGRAMMING: Planning and programming refers to the processes by which transportation plans are created to carry out the goals developed in the consensus-building, needs assessment, and goals-setting processes.

QUESTION: Are the planning and programming functions in this agency best characterized by:

SCORE	STATEMENT	YES/NO
1	• Emphasizes mobility, safety, and quantity (more, faster) within mode • Expands in response to travel demand ("accept and accommodate") • Transportation planning is siloed • Transportation planning is not connected to land use decisionmaking • Limited by political jurisdiction • Limited data and related performance measures	
2	• Emphasizes mobility, safety, and quantity (more, faster), alternate modes • Plans, builds based on forecasts of likely demand ("predict and provide") • Transportation planning is siloed • Transportation planning more influenced by land use decisionmaking • Limited by political jurisdiction • Compliance-based reporting	
3	• Emphasizes mobility etc. but considers flexibility, accessibility, connectivity, system efficiency, and environmental context • Emphasizes improved intermodal operations and environment • Manages transportation demand and capacity • Formal and informal links exist between other planning entities • Plans, builds based on forecasts of likely demand and land use plans • Limited by political jurisdiction • Performance-based reporting, including environment	
4	• Emphasizes flexibility, accessibility, connectivity, system efficiency, safety, security, and context • Emphasizes multimodalism and connections between modes • Proactive demand and capacity management • Stronger planning links with other planning entities • Works from preferred vision to planning and provision ("deliberate and decide")—build scenarios, backcast, deliberate, and decide • Planning and investment decisions are driven by reliable and up-to-date data that reflect the full range of effects of transportation investment	
5	• Emphasizes flexibility, accessibility, connectivity, system efficiency, safety, security, and full TBL context • Emphasizes multimodalism and connections between modes • Proactive demand and capacity management • Emphasizes integrated planning engaging multiple agencies • Works from preferred vision to planning and provision ("deliberate and decide")—build TBL scenarios, analyze, deliberate, coordinate • Flexible regional focus that engages multiple jurisdictions	

C. **BUDGETING AND RESOURCE ALLOCATION:** Budgeting and resource allocation includes the processes by which transportation policy systems determine how to collect and distribute resources among different projects and programs (includes budgeting and allocation).

QUESTION: Are the budgeting and resource allocation functions in this agency best characterized by:

SCORE	STATEMENT	YES/NO
1	• Budget process is competitive (e.g., agencies compete for funds), siloed, and driven by previous allocation decisions (e.g., starts with last year's budget) • Ignores larger social, regional, and economic costs and benefits of transportation—focuses on transportation-centric cost–benefit analysis • Inflexible—funds are bucketed and segregated by rules and policy • Politicized—transportation funding is driven by taxes and formulae	
2	• Budget process is competitive (e.g., agencies compete for funds), siloed, and driven by previous allocation decisions (e.g., starts with last year's budget) • Focuses primarily on immediate direct costs, but does include consideration of social, regional, and economic benefits of transportation • Inflexible—funds are bucketed and segregated by rules and policy • Politicized—transportation funding is driven by taxes and formulae	
3	• Budget process is competitive (e.g., agencies compete for funds), siloed, and driven by previous allocation decisions (e.g., starts with last year's budget) • Incorporate full social, environmental, fiscal, economic, and other costs into planning and provision—uses FCA	
4	• Budget process is more integrated and cooperative • Incorporates social, environmental, fiscal, economic, and other costs into planning and provision—uses FCA • More independent funding—funds for transportation are derived more sustainably from users and other benefiting entities	
5	• Budget process is integrated and cooperative across agency boundaries • Incorporates full social, environmental, fiscal, economic, and other costs into planning and provision—uses FCA • Flexible—funds flow to program areas, regions, and modes where they meet greatest TBL societal sustainability needs • Independent funding—funds for transportation are derived sustainably from users and other benefiting entities	

D. RULEMAKING AND REGULATION: Rulemaking and regulations refers to the processes by which rules, regulations, standards, and guidelines are established for compliance with legislated mandates and laws.

QUESTION: Are the rulemaking and regulation functions in this agency best characterized by:

SCORE	STATEMENT	YES/NO
1	• Expert led • Heavily influenced by organized interests and economic stakeholders • Minimal public involvement	
2	• Expert led • Heavily influenced by organized interests and economic stakeholders • Increased public involvement • Highly politicized and conflict based	
3	• Expert led • Open to a plurality of interests, stakeholders, and activists • Substantial public involvement during post-decisionmaking phase (i.e., "do you approve?") • Highly politicized and conflict based	
4	• Public–expert partnership in developing regulation and rules—experts invite and encourage public participation • Open to a plurality of interests, stakeholders, and activists • Substantial public involvement during the entire rulemaking process • Less politicized and more cooperative	
5	• Public–expert partnership in developing regulation and rules—experts invite and encourage public participation • Bias for flexible, voluntary self-regulation • Open to a broad TBL-related plurality of interests, stakeholders, and activists • Substantial public involvement during the entire rulemaking process • Cooperative and consultative	

E. SERVICE AND PRODUCT DELIVERY: Service and product delivery includes processes by which transportation policy systems deliver transportation goods and services to the public and ensure that the level and quality of services meet goals and established standards.

QUESTION: Are the service and project delivery functions in this agency best characterized by:

SCORE	STATEMENT	YES/NO
1	• Efficient and best-value business processes • Transportation and mobility performance measured and reported	
2	• Ad hoc sustainability initiatives • Efficient and best-value business processes—some environmental and social issues considered • Transportation and mobility performance measured and reported • Some environmental performance management reports	
3	• General sustainability objectives established • Sustainability performance (centered on environment) reporting and management common among delivery functions	
4	• Sustainability embedded in all business processes (e.g., project delivery, procurement, O&M) • Sustainability performance (centered on environment) measured and reported across most functions	
5	• Sustainability embedded in all business processes (e.g., project delivery, procurement, O&M) • Sustainability performance measured and reported with TBL-related improvement targets • Commitment to societal sustainability in all service and project delivery functions • Periodic reevaluation of performance measures and regular evaluation of sustainability achievements	

F. **COMPLIANCE AND DISPUTE RESOLUTION:** Compliance and dispute resolution include processes by which the transportation community sees that the intent of legislation, standards, and regulations are complied with and the processes by which disagreements over interpretations or tradeoffs can be resolved.

QUESTION: Are the compliance and dispute resolution functions in this agency best characterized by:

SCORE	STATEMENT	YES/NO
1	• Highly politicized • Informal brokering between powerful stakeholders	
2	• Highly politicized • Informal brokering between powerful stakeholders • Dependence on law and judicial system • Adversarial relationship between key stakeholder groups	
3	• Highly politicized • Less influenced by powerful stakeholders in the decisionmaking process • Dependence on law and judicial system • Less adversarial relationship between key stakeholder groups and more constructive dialogue	
4	• Emphasizes “deliberate and decide” and constructive engagement • Avoids dependence on law and judicial system	
5	• Politics minimized—public involvement and transparency in compliance issues • Emphasizes “deliberate and decide” and emphasis on constructive engagement to solve problems • Avoids dependence on law and judicial system	

G. EDUCATION AND TRAINING: Education and training includes processes by which the transportation community is educated to understand and embrace evolving organizing principles and to adopt (and invest in) behavioral norms associated with those principles.

QUESTION: Are the education and training functions in this agency best characterized by:

SCORE	STATEMENT	YES/NO
1	• Focus on technical specialties and standards • Performance standards and incentives associated with traditional performance measures	
2	• Focus on technical specialties and standards • Performance standards and incentives associated with traditional performance measures • Informal sustainability training and recruitment and integration of environmental specialists into transportation agencies	
3	• Focus on multidisciplinary workforce—development of more flexible performance standards • Developing sustainability education, training, and internal incentives to support sustainable programs • Culture of environmental stewardship	
4	• Focus on multidisciplinary workforce—organization commitment to flexible performance standards • Commitment to sustainability education, training, and internal incentives to support sustainable programs • Culture of transportation sustainability and stewardship	
5	• Focus on multidisciplinary workforce—established and flexible standards associated with sustainability • Commitment to sustainability education, training, and internal incentives to support TBL sustainability • Culture of TBL sustainability and stewardship of societal well-being	

H. OUTREACH AND COMMUNICATIONS: Outreach and communications include processes by which information on needs, strategies, expectations, and results are shared broadly by stakeholders in the public and private-sector transportation community—critical processes to support consensus-building, policymaking, planning, and decisionmaking.

QUESTION: Are the outreach and communication functions in this agency best characterized by:

SCORE	STATEMENT	YES/NO
1	• One-way communication to explain transportation priorities and plans	
2	• One-way communication to explain transportation priorities and plans with formal requirements to present plans but limited feedback	
3	• One-way communication to explain transportation priorities and plans with highly structured presentation and feedback	
4	• Two-way active engagement and communication between transportation agencies, public, stakeholders, and decisionmakers	
5	• Regular two-way active engagement and communication between transportation agencies, public, stakeholders, and decisionmakers • Involvement of stakeholders at all stages of the decisionmaking and planning process • Active outreach to identify and include previously underrepresented groups	

F.2 Overall Rating—Sustainability Maturity Level

For an overall TBL sustainability maturity rating, review the answers for each of the functional dimensions. For the row that best describes your agency, circle the score in the first column of that row (i.e., 1 through 5). When tables for functional dimensions A through H are completed, enter the scores in the table below and sum for the overall rating.

Functional Dimension	Score
A. Consensus on Needs and Goals	
B. Planning and Programming	
C. Budgeting and Resource Allocation	
D. Regulation and Rulemaking	
E. Service and Product Delivery	
F. Compliance and Dispute Resolution	
G. Education, Training, and Culture Change	
H. Outreach and Communications	
Total (sum A through H)	

Compare the score to the following scale for overall maturity level:

Maturity level	Characteristics	Score
Safe Mobility	• Support societal mobility • Favors government ownership & control of the transportation infrastructure • Transportation agency as infrastructure owner–manager & regulator	8 to 11
Compliant Transportation	• Support societal mobility • Compliance with environmental, economic, and social legislative requirements • Transportation agency as infrastructure owner–manager & regulator • Top-down, planning	12 to 19
Green Transportation	• Support societal mobility & environmental, economic, and social needs—*emphasizes environment* • Transportation agency as infrastructure owner–manager & regulator	20 to 27
Sustainable Transportation	• Support sustainable transportation • Favors partnerships between public and private sector • Transportation agency as infrastructure coordinator & regulator	28 to 36
Support TBL Sustainability	• Support societal sustainability • Agnostic on issues of ownership or control of transportation infrastructure—whatever is most sustainable • Transportation agency as transportation system steward	37 to 40

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation