

Advancing Transportation Systems Management and Operations

Through Scenario Planning



U.S. Department of Transportation
Federal Highway Administration

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U.S. Department
of Transportation
**Federal Highway
Administration**

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In Reply Refer To:
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Dear Colleagues,

The Federal Highway Administration (FHWA) supports the use of scenario planning as a valuable resource for developing robust long-range, multimodal transportation plans. Scenario planning is an enhancement of the planning process that enables more effective decisions by formally considering the “what-ifs?” of tomorrow to support a more resilient and desirable future. While scenario planning is widely recognized as a valuable resource in this regard, FHWA believes that scenario planning also has potential to be an equally useful tool for advancing longer term approaches to the way we want to have our transportation systems managed and operated in the face of changing demands, situations, conditions, and perspectives.

Planning for the way that we want to manage and operate the transportation system is uniquely tied to several factors that are often difficult to predict. For example, travel information, smartphones, and connected vehicle systems may have a significant effect on the way we manage and operate our systems over the next several years. Scenario planning methods can help planners and system managers examine the expanding interplay of issues, technologies, and stakeholders involved in making our transportation systems work more reliably, safely, and effectively. Scenario planning provides a structured approach for consensus-building among multiple agencies, jurisdictions, and stakeholders.

Through this primer, FHWA capitalizes on the strengths of scenario planning and applies its principles to advancing better longer term approaches to the way we want our transportation systems to be managed and operated. It is intended to assist planners, operators, and other partners to make more robust decisions and plans. We look forward to receiving your feedback, reactions, and experience with these concepts. Please direct any comments or suggestions to Mr. Wayne Berman at wayne.berman@dot.gov or 202-366-4069. To download a copy of this report or learn more about the Planning for Operations program, please visit <http://www.ops.fhwa.dot.gov/plan4ops/index.htm>. For more information on FHWA’s overall Scenario Planning Program, please visit <http://www.planning.dot.gov/scenario.asp> or contact Ms. Rae Keasler at rae.keasler@dot.gov or 202-366-0329.

Sincerely yours,

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Director, Office of Transportation Management

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16. Abstract The intent of this primer is to inform planners, operators, and other transportation systems management and operations (TSMO) partners on the potential use of scenario planning to advance TSMO. It builds upon the long standing scenario planning guidance that continues to be advanced by FHWA's Office of Planning, Environment, and Realty. The primer includes an explanation of the "why" behind the use of scenario planning in transportation and presents hypothetical examples to prompt thinking about the "when" and the "how" scenario planning might be used for TSMO. This includes discussions about how to apply scenario planning at multiple geographic scales and in support of several TSMO-focused planning activities, such as developing work zone management or statewide freight mobility plans. While this primer does not provide detailed guidance on how to conduct scenario planning for a specific TSMO effort, it does offer a deeper understanding of scenario planning opportunities and a framework that readers can adapt to their specific needs and use as a guiding tool as they embark upon scenario planning to enhance their TSMO planning and programming decisions.					
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Table of Contents

- Section 1: Introduction 1
 - Purpose 3
 - Overview 4
- Section 2: Understanding Scenario Planning and Its Use in Transportation 5
 - What is Scenario Planning? 5
 - The Origins of Scenario Planning 6
 - Scenario Planning in Transportation 7
 - Federal Highway Administration Scenario Planning Framework 11
 - Using Scenario Planning in Performance-Based Planning and Programming 13
- Section 3: Applying the Scenario Planning Approach to Planning for Transportation Systems Management and Operations 19
 - Federal Highway Administration Scenario Planning Framework Applied to Transportation Systems Management and Operations 20
 - Phase by Phase: Process, Participants, and Outputs 22
 - Analysis Tools and Data to Support Scenario Planning for Transportation Systems Management and Operations 33
- Section 4: Opportunities for Scenario Planning to Advance Transportation Systems Management and Operations 39
 - Regional Opportunities 40
 - Statewide Opportunities 43
 - Corridor Opportunities 46
 - Opportunities to Consider Implications of Emerging Trends 47
- Section 5: Illustrations of Scenario Planning for Transportation Systems Management and Operations 51
 - Southcom Coalition: Planning for Operational Resilience during Tropical Storms 51
 - Corridor Q: Development of a Multimodal Corridor Operations Plan 54
 - Fairview Metro Plan: Development of Regional TSMO Strategies 58
- Section 6: Getting Started 61

List of Figures

Figure 1. Illustration. The Federal Highway Administration’s Six-Phase Scenario Planning Framework.	11
Figure 2. Diagram. Transportation-Related Performance Target For Plan Bay Area.	15
Figure 3. Diagram. Metropolitan Transportation Commission’s Performance-Based Planning Framework.	16
Figure 4. Diagram. The Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.	21
Figure 5. Diagram. Phase 1 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.	22
Figure 6. Diagram. Planning Horizons.	23
Figure 7. Diagram. Phase 2 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.	26
Figure 8. Diagram. Phase 3 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.	27
Figure 9. Diagram. Phase 4 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.	29
Figure 10. Diagram. Phase 5 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.	32
Figure 11. Diagram. Phase 6 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.	33

List of Tables

Table 1. Costs and Benefits of Scenario Planning.	13
Table 2. Transportation Systems Management and Operations Planning Contexts and Sample Scenario Planning Applications.	18
Table 3. Scenario Planning Focal Questions and Outcomes.	24
Table 4. Example Driving Forces to Shape Scenario Logic.	31
Table 5. Sample Operations Objectives for Use in Scenario Planning.	41

Section 1: Introduction

Robust transportation planning and programming decisions are based on a thorough consideration of how conditions may change in the future and how those changes may influence transportation needs. Future conditions ranging from near- to long-term are subject to a range of different influences including financial, technological, political, socioeconomic, and climate factors as well as others. This primer introduces a scenario planning approach that can be used by planners and operators to examine variable future conditions, develop more robust plans, and make better decisions for transportation systems management and operations (TSMO) investments.

The transportation planning process typically involves assessing needs and making recommendations based on considerations of historic trends and forecasts, resulting in a single “most-likely” estimate of future conditions. While this approach works well in some settings, the “predict and plan” method does not enable consideration of how future conditions might change and thereby affect transportation needs. The single forecast method also limits planners’ ability to simultaneously look at the interplay of different factors on traveler behavior and levels of travel demand and how those factors can be optimized to achieve broader public policy goals such as livability. To address the limitations of predict and plan methods, transportation planning professionals are increasingly using scenario planning as a method to inform better decisionmaking. Scenario planning provides a framework to help planners and interested stakeholders consider issues and opportunities associated with uncertain futures or new desirable futures that are very different from conditions today.

Scenario planning in transportation is not focused on utopian or ideal futures, rather it is a method that enables a more effective decisionmaking process that takes into account the “what-ifs?” and the longer term strategies needed to help make transportation investment decisions that support a more resilient and desirable future. Scenario planning is an enhancement of the planning process rather than a replacement. It can result in a reconfirmation of existing goals, objectives, policies, and investment decisions and it can highlight the need to make policy, programming, or investment priority changes.

What is TSMO?

Transportation systems management and operations (TSMO) encompasses a broad set of strategies that aim to optimize the safe, efficient, and reliable use of existing and planned transportation infrastructure for all modes. TSMO is undertaken from a systems perspective, which means that related TSMO strategies are coordinated with each other and across multiple jurisdictions, agencies, and modes. TSMO includes both efforts to operate the multimodal transportation system and activities to manage travel demand. The following are examples of TSMO strategies:

- Traffic incident management.
- Traffic signal coordination.
- Transit signal priority.
- Freight management.
- Work zone management.
- Special event management.
- Road weather management.
- Congestion pricing.
- Managed lanes.
- Ridesharing programs.
- Parking management.

Scenario planning in transportation is typically applied to a long-range transportation planning process. Often led by metropolitan planning organizations (MPO), scenario planning in transportation most often is used to support community efforts to establish visions that help identify specific development and transportation policies and investments that can in turn help support long term goals. However more recently, MPOs and departments of transportation (DOT) have begun using scenario planning to provide insights on the potential impacts of evolving technology, climate change, shifting traveler behavior, financial uncertainty, failing infrastructure, natural and man-made events, and other unknowns so that they can be factored into planning and programming decisions. Scenario planning is also being used in response to changing public policies and a call for new measures of transportation performance that

address broader livability goals, such as increasing transportation choices or improving accessibility rather than simply looking at measures to reduce congestion or enhance vehicular mobility.

As the use of TSMO strategies expands in States and regions across the United States, the importance of making effective planning and programming decisions for TSMO increases. To date, most scenario planning for transportation occurs over a longer term horizon, but scenario planning can also enhance shorter term planning and investment decisions. It has not been applied to TSMO-focused planning efforts, but given the benefits to long-range transportation planning, scenario planning holds promise for improving planning for TSMO as well.

Planning for the management and operation of the transportation system is uniquely tied to several factors that are difficult to predict. For example, TSMO is supported by rapidly advancing technology, which will soon include connected vehicle systems. In addition, the Nation's aging infrastructure conditions and climate change present planning challenges for TSMO in maintaining safety and mobility during and

after unplanned events such as a hurricane or bridge failure. Addressing issues of uncertainty in TSMO planning could include the development of scenarios that look at different response times to major weather incidents, or look at system-level operational needs if a large shift to automated vehicles occurs in the next 10 years.

Transportation systems management and operations proactively addresses transportation system user needs by:

- Influencing travel demand in terms of location, time, and intensity of demand.
- Managing trips effectively.
- Anticipating and responding to planned and unplanned events such as traffic incidents, work zones, inclement weather, and special events.
- Providing travelers with high quality information.
- Ensuring that the unique needs of the freight community are considered and included in all of the above.

Source: Federal Highway Administration, Office of Operations, The Operations Story, Presentation, 2012, Jeffrey A. Lindley.

Scenario planning also offers opportunities to revisit common TSMO performance measures with a focus on improving the safety, efficiency, and reliability of travel and goods movement through a broader set of multimodal management and operational strategies. It also offers an opportunity to identify new measures (e.g., multimodal accessibility) and potentially new data needs that can address the growing importance and interest in the transportation user experience and transportation on demand. In sum, scenario planning offers TSMO practitioners a new framework for planning that can facilitate better transportation decisionmaking.

Purpose

The intent of this primer is to inform planners, operators, and other TSMO partners on the use of scenario planning to advance TSMO including why and when to use it and how to apply the phases of scenario planning to TSMO. This primer is also meant to promote thinking about the broad range of opportunities for using scenario planning for TSMO by providing hypothetical examples and discussions about applying it at multiple geographic scales and for several TSMO-focused planning activities, such as developing work zone management or statewide freight mobility plans. While this primer does not provide detailed guidance on how to conduct scenario planning for a specific TSMO effort, it does promote a deeper understanding of scenario planning opportunities and offers a framework that readers can adapt to their specific needs and use as a guidance tool as they embark upon scenario planning to enhance their TSMO planning and programming decisions. This primer does not focus on the use of scenarios to direct real-time operations decisions such as where traffic should be rerouted when a traffic incident blocks all lanes of a specific part of a highway. While using scenarios to create response plans is a common and useful effort, it is different than the more strategic level of planning described in this primer and does not require the scenario planning framework described here.

The audience for this primer is anyone who may lead or participate in an effort to plan for TSMO, either formally or informally. This includes transportation planners, operations professionals, and stakeholders at the statewide, metropolitan, rural, corridor, and local levels who contribute to decisions on how the transportation system should perform in terms of reliability, efficiency, and accessibility and what is necessary to reach that level of performance. Professionals whose work involves integrated corridor management (ICM), advanced transportation and demand management (ATDM), traffic incident management, transit operations, work zone management, road weather management, transportation management center (TMC) operations, travel demand management, and many other areas of TSMO will also find this primer useful. Finally, this primer is also intended to address the needs of those who engage in scenario planning to support the development of long-range transportation plans and other transportation plans that include TSMO.

Overview

This document is organized around six sections that help to give the reader a clear understanding of scenario planning and how they can use it to advance TSMO.

Section 1: Introduction provides the context and motivation for the use of scenario planning for TSMO. It also orients the reader to the purpose of the primer and its intended audience.

Section 2: Understanding Scenario Planning and its Use in Transportation discusses what scenario planning is and its origins. It also examines how scenario planning is used in transportation planning with an emphasis on its role in performance-based planning and programming.

Section 3: Applying the Scenario Planning Approach to Planning for Transportation Systems Management and Operations lays out a framework for using scenario planning for TSMO in six phases from “How should we get started?” to “How will we reach our desired future?”

Section 4: Opportunities for Scenario Planning to Advance Transportation Systems Management and Operations explores the range of opportunities to apply scenario planning to TSMO planning efforts.

Section 5: Illustrations of Scenario Planning for Transportation Systems Management and Operations provides readers with a step-by-step look at three hypothetical examples of scenario planning for TSMO in different contexts, driven by different motivations, and using different types of scenario planning.

Section 6: Getting Started concludes the primer and offers a list of questions to help planners and operators begin to scope their scenario planning effort for TSMO.

Section 2: Understanding Scenario Planning and Its Use in Transportation

What is Scenario Planning?

Scenario planning is an approach to strategic planning that uses alternate narratives of plausible futures (or future states) to play out decisions in an effort to make more informed choices and create plans for the future. From a transportation systems management and operations (TSMO) perspective, a future state or condition might include narratives that prompt planners and stakeholders to consider what kind of TSMO response might be appropriate to different types (or frequency) of significant weather events, a future that assumes a more significant shift in traveler behavior to non-auto modes, or a future where 30 percent of the vehicles on the road are essentially “driverless.” Considering scenarios like these can result in the identification of new technology or data needs, new technology investments, more communication and coordination across emergency response stakeholders, new multimodal TSMO strategies, and other insights that can be factored into both short- and long-term TSMO plans and programs.

Scenario planning helps participants to consider the “what-ifs” of tomorrow, whether those are desirable or undesirable states. The simple task of imagining a different future can help to challenge the status quo and encourage creative thinking, which ultimately can lead to the development of more thoughtful and resilient plans. Scenarios are developed to enable participants to test out possible decisions, analyze their impacts given the conditions in each scenario, and come to an agreement on a preferred course of action.

There are many definitions for scenario planning throughout literature and there are several variants on how to develop and use scenarios. Despite these variations, there are commonalities that provide structure to scenario planning. Scenarios are seen as “an internally consistent view of what the future might turn out to be – not a forecast, but one possible future outcome.”¹ This definition combines three key characteristics of scenarios:

- Scenarios are internally consistent, depicting an array of conditions that could logically co-exist.
- Scenarios are plausible, depicting a future that could evolve from current conditions, even if it is very different from the present.
- Scenarios are conjectural rather than factual. They focus on broad implications as opposed to detailed predictions.

Scenarios are neither forecasts nor predictions for a given point in time; instead, they represent alternative possible futures. They enable planners to consider a range of possible consequences

¹ M. Porter, *Competitive Advantage* (New York: Free Press 1985).

of those futures and then to identify robust strategies or policy options that best “hold up” across the spectrum of possible future conditions. Scenario planning “formalizes the consideration of uncertainty in the planning process.”²

Peter Schwartz, an international leader in the field of scenario planning, describes scenarios as “the best tool I know to allow the conversation to reflect different perceptions of the situation (differentiation), but in such a way to create room for people to consider these different viewpoints and gradually align on what needs to be done, and what they want to do (integration).”³

Advantages of Scenario Planning:

- Accommodates uncertainty and ambiguity.
- Helps communities prepare for a range of plausible futures rather than a single forecast.
- Results in decisions that are more robust in a variety of futures.
- Provides a forum for engaging a diverse set of stakeholders to identify critical factors.
- Facilitates testing out possible decisions and their impacts on multiple future scenarios.
- Encourages system-level thinking.
- Fosters a more adaptive, resilient organization.

Scenario planning supports a dynamic planning process that can help demonstrate the causal relationships of different variables and how they combine to create different outcomes. This gives people the freedom to imagine that conditions could change in the future if given enough time. In the public sector, scenario planning is often applied to provide a forum for engaging diverse stakeholders, illustrating comparisons and discussing tradeoffs, and encouraging systems-level thinking that breaks down the silos of specialization to address challenging public policy issues. It helps people to envision not only what the future might be but also what kind of future people actually want. Scenario planning is a more deliberate process that uses empirical data and quantitative analysis to develop plausible scenarios.

The Origins of Scenario Planning

The origins of scenario planning in modern America are attributed to military planning methods that were developed during World War II and extended into the Cold War and beyond. The Air Force and other branches of the military would routinely envision possible combat scenarios and devise strategies to overcome their opponents.⁴ In the 1950s and 1960s, the RAND® Corporation helped to pioneer the science of scenario analysis, which relies on game theory. By the late 1960s, scenario planning was being applied regularly in corporate settings and has remained a common practice in business today. One of the seminal scenario planning efforts occurred in the 1970s when Royal Dutch Shell used scenario planning to prepare for potential events causing oil prices to change. In part due to that effort, Royal Dutch Shell was able react quickly to the fuel shortage

² J. Zmud, Transportation Research Board Webinar, “Applying Scenario Methods to Transportation Planning and Policy,” October 23, 2014. Slides available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_750v1.pdf.

³ P. Schwartz, as quoted in Kees van der Heijden, *Scenarios: The Art of Strategic Conversation* (New York: Wiley and Sons, 2005).

⁴ C. Caplice and S. Phadnis, *NCHRP Report 750: Strategic Issues Facing Transportation, Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment* (Washington, DC: National Cooperative Highway Research Program, 2013). Available at: <http://www.trb.org/main/blurbs/168694.asp>.

and high oil prices set off by the Organization of Petroleum Exporting Countries' oil embargo of 1973.⁵ The company continues to practice scenario planning to this day.⁶

Scenario Planning in Transportation

In transportation, scenario planning began taking hold in the United States in the early 1990s as a method to help support alternative analysis practices developed under the National Environmental Policy Act and the “3C” (comprehensive, continuous, coordinated) systems planning requirements of the Federal-Aid Highway Act of 1962.⁷ In the early 2000s, the Transportation and Community and System Preservation Pilot Program (TCSP) resulted in the creation of some of the early tools and processes for incorporating scenario planning into the development of long-range transportation plans. These early efforts focused almost entirely on examining alternative land-use and transportation futures that emphasized desirable stories and narratives for how communities wanted to grow. As a result, many of the early scenario planning processes resulted in public policy shifts that enabled much stronger links between land use and transportation planning.

More recently, scenario planning in transportation has begun to examine a broader range of variable relationships beyond just land use and transportation. These include scenarios that take into account goals and objectives related to housing affordability, economic competitiveness, adapting to climate change, water conservation, fiscal sustainability, public health, and energy conservation. This broadening of factors is generating more integrated plans and policies as communities gain a better understanding of the connections between factors such as housing affordability and transportation accessibility or reductions in vehicle miles traveled (VMT) and better public health outcomes.

⁵ C. Caplice and S. Phadnis, *NCHRP Report 750: Strategic Issues Facing Transportation, Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment* (Washington, DC: National Cooperative Highway Research Program, 2013). Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_750v1.pdf.

⁶ Shell Global, “40 years of Shell Scenarios,” Web Page. Available at: <http://www.shell.com/global/future-energy/scenarios/40-years.html>.

⁷ K. Bartholomew and R. Ewing, *Integrated Transportation Scenario Planning*, Metropolitan Research Center, University of Utah. July 2010.

Key Elements of Scenario Planning

“While scenario planning can be implemented in many ways, the key elements include:

- Use of scenarios to compare and contrast interactions between multiple factors, such as transportation, land use, and economic development;
- Analysis of how different land-use, demographic, or other types of scenarios could impact transportation networks;
- Identification of possible strategies that lead a State, community, region, or study area toward achieving elements of the preferred future; and
- Public engagement throughout the process.

Scenario planning shares common elements with both alternatives analysis and visioning exercises, but primarily differs from these processes in examining interactions between multiple factors, including both internal and external forces, as a way to assess possible future outcomes.”⁸

Scenario planning is making a difference in areas where it is used as part of transportation planning efforts. **Scenario planning can help agencies to convey critical information to policy makers and elected officials who make investment decisions.** For example the Colorado Department of Transportation (CDOT) addressed the linkages between funding and system management performance in its 2035 statewide plan by constructing three investment scenarios, each of which forecasted anticipated performance based on investment levels. Given forecasted revenues, pavement condition would deteriorate to the point at which only 25 percent of roads would be in good/fair condition, while congestion would increase to 70 minutes of delay per traveler. CDOT developed alternative revenue scenarios to demonstrate the “cost to sustain current performance” and the “cost to accomplish [a] vision” that had been laid out in the statewide long-range plan. This valuable information helped decision makers to clearly understand how funding shortfalls would affect system performance.

Scenario planning helps agencies to build relationships and forge partnerships that can strengthen their effectiveness and build their capacity. For example, the Champaign-Urbana Urban Area Transportation Study (CUUATS), the metropolitan planning organization (MPO) for a university town in Illinois, has applied scenario planning techniques to a series of studies that engaged an ever-expanding array of interest groups and agency stakeholders. The resulting strong relationships with various local and State agencies and other organizations (including the University of Illinois at Urbana-Champaign) have been critical to CUUATS for obtaining data, developing innovative technical analysis tools, leveraging transportation investment funds, and building political support for regional initiatives. Long-range planning and scenario planning processes have worked smoothly in significant part because of the high degree of collaboration and coordination among local agencies.

⁸ U.S. Department of Transportation, Federal Highway Administration, *Scenario Planning Guidebook* (Washington, DC: FHWA, 2011). Available at: https://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/scenario_planning_guidebook/.

Scenario planning can help transportation practitioners and policymakers better prepare for the future by encouraging an examination of different future conditions that get beyond just an extrapolation of current trends. As explored in the *National Cooperative Highway Research Program (NCHRP) Report 750: Strategic Issues Facing Transportation*, there are several key trends that will significantly impact transportation in the coming decades. Scenario planning can be a useful tool for better understanding the potential impacts of those trends and planning accordingly for system resiliency, shifts in travel behavior and travel demand, and the rapid advances in technology.

Scenario Planning to Strategically Address Driving Issues Affecting the Future of Transportation

The National Cooperative Highway Research Program (NCHRP) issued *NCHRP Report 750: Strategic Issues Facing Transportation* in an effort to compile research and provide practitioner guidance for addressing climate change, socio-demographic shifts, technology advances, freight and goods movement, alternative energy and fuels, and sustainability. These six topic areas are seen as having a significant impact on how we will plan, fund, build and operate our transportation systems in the future. Six separate reports summarize these research efforts:

Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment

Volume 2: Climate Change, Extreme Weather Events, and the Highway System – Practitioner’s Guide and Research Report

Volume 3: Expediting Future Technologies for Enhancing Transportation System Performance

Volume 4: Sustainability as an Organizing Principle for Transportation Agencies

Volume 5: Preparing State Transportation Agencies for an Uncertain Energy Future

Volume 6: The Effects of Socio-Demographics on Future Travel Demand

The documents are available at:

<http://www.trb.org/NCHRP750/ForesightReport750SeriesReports.aspx>.

Each report addresses issues relevant to long-term thinking about management and operations, offering again some key drivers that could help transportation systems management and operations (TSMO) planners envision different scenarios and appropriate corresponding management and operations responses. For example, Volume 2 provides a practitioner’s guide and research on specific weather and climate trends as well as how those conditions may potentially impact events on the highway system. It cites several adaptation strategies that will likely be needed for transportation agencies with respect to network operations:

- Greater progress in surveillance and monitoring.
- More sophisticated data management to enable better predictive models of future trends.
- More effective decision support technology tied to common approaches and treatments for mitigating impacts.

Scenario Planning to Strategically Address Driving Issues Affecting the Future of Transportation (Continued)

- New operational practices for extreme weather events relative to evacuations, detours, closings, etc. tied to real-time weather and traffic information.
- More effective communications and information dissemination.
- Greater advances in agency organizational changes and capacity building to ensure more integrated interagency relationships.

Given the emerging science and research on climate change, scenario planning techniques may be useful in helping TSMO planners and other stakeholders determine how best to identify and incorporate adaptation strategies into regional TSMO plans. In particular, considering that extreme weather events are predicted to increase in many regions across the country, scenario planning could be an effective approach to helping States and metropolitan planning organizations (MPOs) bring together the interagency stakeholders needed to effectively address the issue. Doing so will not only bring the right people to the table, it may also aid in helping to set expectations among planners and even the general public on acceptable levels of system performance under extreme conditions. Finally, the scenario process might also aid the region in better understanding its areas of susceptibility, thereby further helping to refine and strategically deploy TSMO strategies.

The NCHRP Report 750 series not only contains information on some of the driving factors that will influence transportation in the future, it also includes specific examples and tools for using scenario planning as a means for addressing those factors.

Federal Highway Administration Scenario Planning Framework

In 2011, the Federal Highway Administration (FHWA) published the FHWA *Scenario Planning Guidebook*, which outlines key phases associated with transportation scenario planning, as illustrated in Figure 1.



Figure 1. Illustration. The Federal Highway Administration’s Six-Phase Scenario Planning Framework.⁹

⁹ U.S. Department of Transportation, Federal Highway Administration, *Scenario Planning Guidebook* (Washington, DC: FHWA, 2011). Available at: http://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/scenario_planning_guidebook/.

The guidebook offers a structure for scenario planning that aligns well with traditional transportation planning processes. The guidebook focuses primarily on how to apply scenario planning on a regional scale; however, these same phases and steps can be applied to statewide, corridor-level, or neighborhood-level approaches and across short-term or long-term planning horizons. Per FHWA, these are suggested phases, but each location using scenario planning has unique situations, and these phases can be adjusted to fit each community's individual needs. For example, some communities might be much further along in their data collection efforts and could skip Phase 2.

Types of Scenario Planning

Predictive

Allows for modeling or examination of different scenarios in response to probable trends (e.g., higher population growth, lower revenues, etc.). Forecasts have some level of probability of occurring within the planning horizon. The purpose here is to identify scenarios (transportation packages) that are effective in light of those probable trends.

Normative

Allows for modeling or examining different scenarios that depict desirable future conditions (e.g., we want to dramatically increase mode split or change development patterns, we want to increase the use of driverless cars to 50 percent). Scenarios describe different visions of desirable future conditions and explore different ways of achieving each vision. The purpose of the process is to build consensus on desired future conditions and to identify potential policy changes and investment strategies that would best support those conditions.

Exploratory

Allows for modeling or examining different scenarios in response to uncontrollable or unknown future conditions (e.g., we want to better understand impacts of global trade changes, extreme weather, etc.) The purpose of this type of planning is to lead stakeholders to identify policies, plans, and strategies that can work best under all extreme conditions.

- **Phase 1.** The leaders of the scenario planning effort bring together a broad set of relevant stakeholders and scope the effort.
- **Phase 2.** Practitioners establish the baseline information and data needed to identify 10-, 20-, or 50-year trends and other information relevant to revealing insights into travel demand, economic drivers, and other important factors that could influence system-wide transportation dynamics.
- **Phase 3.** Building upon their understanding of the existing public policy context and future trends, the leaders of the scenario planning effort work with the stakeholders to identify values, goals, and priorities.
- **Phase 4.** The scenario planning leaders guide stakeholders in creating different narratives or scenarios for the future; e.g., 5-, 10-, 20-, or 30-year projections. These projections are driven by the public policy goals, objectives, and values identified during Phase 3 to define a desirable future or futures that take into account “what-if” conditions that could arise outside of the public policy level of influence (e.g., inclement weather, new technology, significant financial or economic shifts). This phase also includes the development of a set of measures or key indicators that can provide quantitative and qualitative analysis for scenario comparisons. Following the development of scenarios, strategies necessary to bring about each potential future must be identified.
- **Phase 5.** The relative impacts of each scenario are compared and analyzed based on a pre-determined set of indicators or performance measures.

- **Phase 6.** The scenario planning process concludes with stakeholders crafting a preferred vision, strategies to accomplish the vision, and performance measures to track progress in achieving that vision.

This use of scenario planning has several benefits as well as costs in terms of a lead organization’s human and technical resources as shown in Table 1.

Table 1. Costs and Benefits of Scenario Planning.

	Benefits	Costs
Human Resources	<ul style="list-style-type: none"> • Deeper expertise. • Expanded partnerships. • Broader awareness and support for new initiatives. 	Time, effort, and/or funding required for: <ul style="list-style-type: none"> • Capacity building. • Stakeholder engagement. • Conflict management.
Technical Resources	<ul style="list-style-type: none"> • Enriched datasets. • Robust, defensible decision support. 	Time, effort, and/or funding required for: <ul style="list-style-type: none"> • Data development. • Analysis tools.

Using Scenario Planning in Performance-Based Planning and Programming

Scenario planning is an important tool for performance-based planning and programming and is specifically encouraged by Moving Ahead for Progress in the 21st Century Act (MAP-21) for the development of metropolitan transportation plans.¹⁰ The passage of the MAP-21 in 2012 created requirements for performance-based planning and programming (PBPP) within metropolitan, statewide, and nonmetropolitan decisionmaking. PBPP applies performance management principles to transportation planning and programming to achieve desired performance outcomes for the multimodal transportation system. This is accomplished by incorporating goals and objectives, performance measures and targets, and regular progress reporting into transportation decisionmaking.

Scenario planning can be used at multiple points within the PBPP process to help stakeholders determine their desired strategic direction. Starting with a baseline analysis (“where are we now?”), scenario planning enables stakeholders to establish future aspirations based on their values. This process can involve a specific discussion of goals, supporting objectives, and performance measures based on these values.

¹⁰ 23 USC Section 134(i)(2)(C).

The scenario planning approach helps visualize and articulate, in both qualitative and quantitative terms, how the combination of strategies would help meet public policy goals and performance targets. It allows for the consideration of how various factors, such as revenue constraints, demographic trends, economic shifts, or technological innovation, can affect a State or region and its transportation system performance. The analysis may allow stakeholders to explore the trade-offs between future scenarios, assess the impacts of external factors such as the economy and growth, and select a future vision and investment priorities that bring them closest to their desired performance outcomes.

Through the use of scenario planning, metropolitan, statewide, and other planning organizations are able to take a comprehensive approach to PBPP by exploring multiple potential futures and making a well-informed selection of a preferred alternative with the most potential for supporting priorities and performance targets.

The following text box provides two examples of scenario planning applied to broader planning contexts in which TSMO is one of multiple solutions brought together to address a problem or achieve a vision.

Plan Bay Area

The Metropolitan Transportation Commission (MTC), the metropolitan planning organization (MPO) for the San Francisco Bay Area, and the Association of Bay Area Governments (ABAG) used scenario planning as part of their performance-based planning approach to developing the California Bay Area’s integrated land use, housing, and long-range transportation plan, called *Plan Bay Area*.

First, the agencies developed performance targets for the plan. The transportation-related performance targets they identified are shown in the figure below. The agencies then developed scenarios containing different combinations of growth patterns, transportation, and land-use strategies and analyzed them to see which scenarios came closest to achieving the performance targets. The agencies used different tools to analyze each performance target. For Target 9 (see Figure 2), MTC’s activity-based Travel Model One was used, and for Target 10, post-processing methodologies developed by MTC were used to estimate future road and transit conditions.¹¹

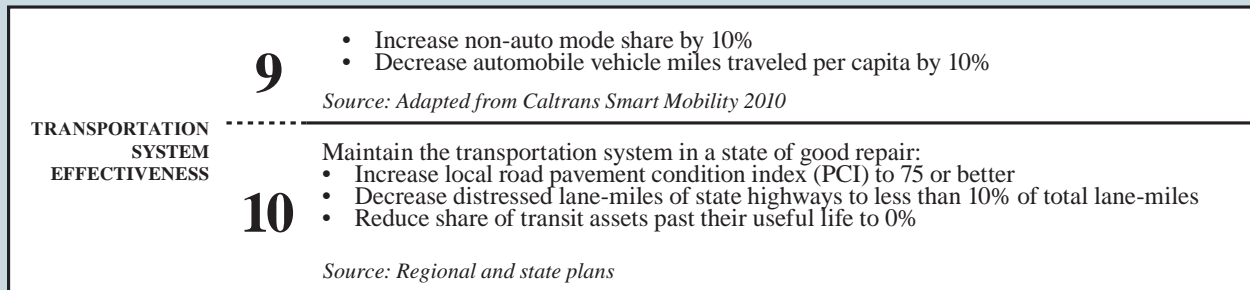


Figure 2. Diagram. Transportation-Related Performance Target For Plan Bay Area.¹²

MTC and ABAG conducted two rounds of developing and analyzing scenarios, which included investments in programs such as a Freeway Performance Initiative (which included intelligent transportation systems (ITS), ramp metering, traffic operations systems, arterial management strategies) and an express lanes network.¹³ The quantitative analysis showed that none of the scenarios were able to meet all of the specified performance targets, and some of the targets were not met by any of the scenarios. In addition, to analyze the scenarios, the agencies conducted assessments of all non-committed transportation projects contained within the scenarios.

Several findings resulted from the project-level assessments. First, ITS technologies and congestion pricing programs proved to be highly cost effective and met many performance targets. In addition, the results showed that express lanes are only moderately cost-effective due to high capital costs, and they tend to increase automobile capacity, which negatively impacted performance targets.¹⁴

¹¹ Association of Bay Area Governments and Metropolitan Transportation Commission, *Plan Bay Area – Performance Assessment Report*, July 2013. Available at: http://onebayarea.org/pdf/final_supplemental_reports/FINAL_PBA_Performance_Assessment_Report.pdf.

¹² Ibid.

¹³ Metropolitan Transportation Commission, *Transportation 2035*. Available at: <http://mtc.ca.gov/our-work/plans-projects/plan-bay-area-2040/transportation-2035>.

¹⁴ Ibid.

Plan Bay Area (Continued)

As a result of the project-level assessments, high-performing projects were incorporated into the transportation strategy included in the “preferred scenario” developed in the spring of 2012. This scenario, called the “Jobs-Housing Connection Strategy,” included a transportation investment strategy that “devotes 87 percent of funding to operate and maintain the existing transportation network.”¹⁵

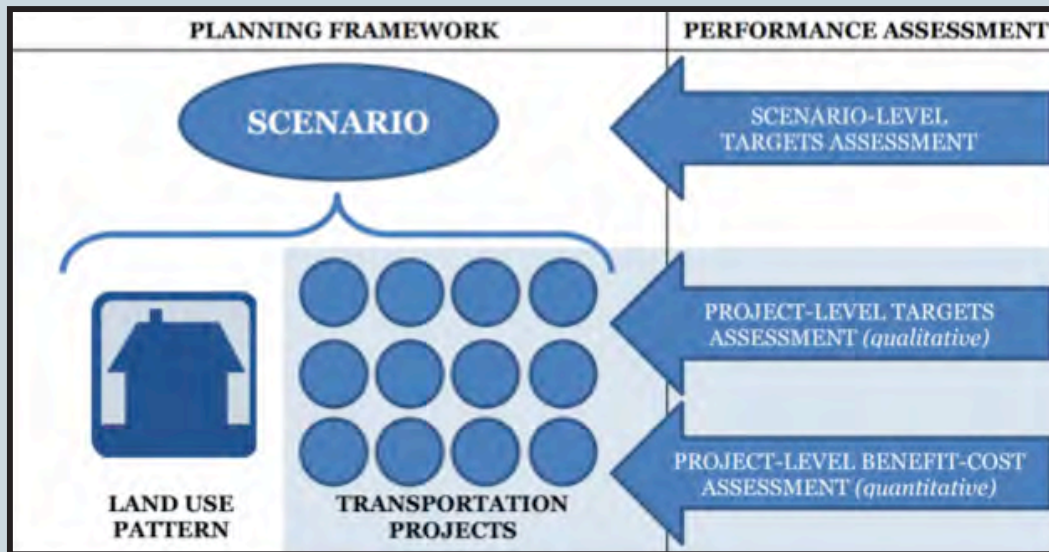


Figure 3. Diagram. Metropolitan Transportation Commission’s Performance-Based Planning Framework.¹⁶

¹⁵ Association of Bay Area Governments and Metropolitan Transportation Commission, *Plan Bay Area – Performance Assessment Report*. July 2013. Available at: http://onebayarea.org/pdf/final_supplemental_reports/FINAL_PBA_Performance_Assessment_Report.pdf.

¹⁶ Ibid.

“What Would It Take?” Scenario Study in the National Capital Region

The Metropolitan Washington Council of Governments’ Transportation Planning Board (TPB) conducted the “What Would it Take?” Scenario Study in 2010 to identify strategies to help the region achieve its greenhouse gas emissions reduction goals. To complete the study, the TPB conducted an emissions baseline inventory and forecast for the region and determined three sources for reducing emissions: fuel efficiency, alternative fuel, and travel efficiency. Then they identified 37 potential transportation strategies that could be used to reduce emissions and used sketch planning methods to analyze each of these strategies individually for emissions reduction potential, cost-effectiveness, and timeframe for implementation. The top scoring strategies were grouped into two categories or scenarios based on the level of government that would be implementing the strategies: ¹⁷

High Federal Role – Examines the impact of “hypothetical, large-scale action taken by the federal government,”¹⁸ including enhanced light duty and heavy duty Corporate Average Fuel Economy (CAFE) standards and high gas prices.

State/Regional/Local Action – Examines the impact of current Federal legislation combined with short-term and long-term actions undertaken by State and local governments. Short-term (pre-2020) actions include strategies such as transit signal priority, incident management, traffic signal optimization, and transportation demand management (TDM) programs. Long-term actions include increasing non-auto mode share, implementing pricing on new and existing roadways, and reducing travel through transit-oriented land-use development.

The study results showed that while neither category would meet the region’s emissions reduction goals, the short-term scenario strategies “position the region toward meeting early targets.”¹⁹ The study team concluded that meeting the emissions reduction goals would require incorporating more aggressive strategies into all of the scenario categories and conducting additional analysis.²⁰

There are many contexts in which scenario planning can be used to advance TSMO. In the Plan Bay Area and National Capital Region “What Would it Take?” planning efforts, the scope included TSMO as one of many transportation strategies. Alternatively, scenario planning can be used to look exclusively at TSMO and answer the questions necessary to create TSMO-oriented plans or make decisions about how to move ahead with TSMO goals, objectives, strategies, and investments. This primer will discuss several opportunities and hypothetical illustrations of using scenario planning for TSMO. As a preview, Table 2 provides a sample of the TSMO contexts for scenario planning use that will be covered in later sections.

¹⁷ M. Bansal and E. Morrow, Metropolitan Washington Council of Governments, “Meeting Transportation Greenhouse Gas Reduction Goals in the National Capital Region: A ‘What Would it Take’ Scenario,” July 2010. Available at: http://www.mwcog.org/clrp/elements/scenarios/whatwouldittakeTPB_TRB_Resubmit.pdf.

¹⁸ Ibid., p. 10.

¹⁹ National Capital Region Transportation Planning Board, *What Would it Take? Transportation and Climate Change in the National Capital Region, Final Report*, May 2010, p. vii. Available at: <http://www.mwcog.org/uploads/committee-documents/kV5YX1pe20100617100959.pdf>.

²⁰ Ibid.

Table 2. Transportation Systems Management and Operations Planning Contexts and Sample Scenario Planning Applications.

Transportation Systems Management and Operations (TSMO) Planning Context	Sample Scenario Planning Application
<p>Developing a regional TSMO plan to provide input into the development of the region’s metropolitan transportation plan.</p>	<p>Option 1: Formulate and reach consensus on a set of operations objectives for the regional TSMO plan that are most effective in helping to achieve the goals from the metropolitan transportation plan. Scenarios take into account competing priorities.</p> <p>Option 2: Analyze the effectiveness of different packages of TSMO strategies relative to different levels of TSMO funding or data availability. This would help to identify TSMO strategies that best meet operations given unknown funding or data availability levels.</p>
<p>Forming a statewide investment plan for TSMO.</p>	<p>Examine three main TSMO investment approaches, drawing from nine investment categories and using portfolios to describe what the 10- to 15-year outcomes of each approach would look like from the traveler’s perspective.</p>
<p>Transportation management center (TMC) strategic planning for technology investments, staffing levels, and other costs.</p>	<p>Explore alternative futures with regard to increased extreme weather events and vehicle automation and determine how best to prepare the TMC for those potential realities.</p>
<p>Creating a work zone transportation management plan for a significant highway reconstruction project.</p>	<p>Identify and analyze the impacts of a few different TSMO approaches to managing the travel impacts of the work zone and develop a preferred approach based on stakeholder input and analysis of impacts.</p>

Section 3: Applying the Scenario Planning Approach to Planning for Transportation Systems Management and Operations

Wherever transportation infrastructure exists, communities face the challenge of planning to manage and operate it. Transportation systems management and operations (TSMO) planning occurs at all geographic scales, including local, corridor, subregional, regional, metropolitan, statewide, and multi-state. TSMO planning efforts range from informal to formal and cover a spectrum of temporal scales—from a few weeks to many decades. In addition, the functional scope of TSMO planning may be a single TSMO strategy or program (e.g., regional signal coordination, transportation management centers, traffic incident management) or all TSMO strategies and every combination in between. While the scenario planning approach could be used in any of these contexts, this primer will illustrate how scenario planning can be incorporated into a handful of TSMO planning efforts.

Scenario planning can create a more robust and effective approach to planning for TSMO in a variety of contexts. The scenario planning approach can confer benefits for all TSMO planning efforts, especially in cases where there is a significant level of uncertainty about the future or there is a need to resolve conflicts about how a particular area or corridor might develop over time.

The scenario planning approach can be particularly effective for TSMO planning when the transportation service providers and other stakeholders must arrive at decisions about operations when there are differing assumptions about future events, trends, policies, or other factors that will significantly impact the successful outcomes of operations decisions. For example, scenario planning can help a region decide how to invest in road weather management or hurricane evacuation operations given the uncertain impacts of climate change on weather patterns in the region. Alternatively, it could be applied in planning for intelligent transportation systems (ITS) equipment investments for a State’s highway system over the next 5 years given the uncertainty in the pace and direction of technological innovations.

Similarly, scenario planning can be effective when the stakeholder visions for an area are unclear or there are competing visions and goals about how an area should evolve. For instance, a stakeholder community may have differing ideas regarding the purpose and design of a street. One segment of the community may push to redevelop the street into a multimodal, suburban “Main Street” with development fronting the street, while another faction may be adamant about maintaining high-speed mobility for regional travelers by controlling vehicular access to adjacent development. Scenario planning could help the stakeholders develop a range of different futures that illustrate the tradeoffs of different corridor approaches and help clarify a preferred vision that sets the framework for identifying specific TSMO strategies to support that vision.

In a TSMO context, the focus of the effort is not just on the road and land-use development patterns per se, but rather the TSMO-specific strategies to help optimize and improve the operations and management necessary for meeting travelers' needs. Typical considerations in a TSMO scenario planning process could include identifying strategies that address how long it takes to travel along a facility by different modes, what types of design features and amenities should be provided to various travel modes, or what new information technology and communications could be implemented to provide more accurate real-time travel times or options for different users. The primary goal of scenario planning is to identify a set of preferred TSMO strategies in response to a robust consideration of tradeoffs associated with different public policy goals or future uncertainties. Strategies such as increasing transit service and encouraging more non-motorized travel may be part of any solution, and will include the examination of multimodal metrics such as auto and non-auto travel time. Looking at these types of metrics will help stakeholders identify strategies to support improved transportation system management and operations. In addition, scenarios aimed at creating more resilient transportation systems might include identification of new investments needs in communication networks or identifying new measures or targets for getting the transportation system operational after a major weather event.

The general approach to scenario planning provided by the Federal Highway Administration (FHWA) in its 2011 FHWA *Scenario Planning Guidebook*²¹ offers a useful structure to planners and operators as they shape their scenario planning effort for TSMO. This section looks closely at each phase in FHWA's scenario planning approach and describes how the scenario planning leaders would conduct each phase in the context of advancing TSMO, including the important questions to address. This section also distinguishes and clarifies the desired outputs during each phase. The end of this section provides an overview of analysis tools and models that could be used to support scenario planning for TSMO activities.

Federal Highway Administration Scenario Planning Framework Applied to Transportation Systems Management and Operations

Figure 4 depicts the FHWA 2011 scenario planning framework, adapted to apply to TSMO planning contexts. The figure uses the same six phases as the FHWA scenario planning approach but defines each phase as it applies to TSMO. Instructions or questions to consider in the left column provide quick guidance on actions to take or questions to consider during each phase. The diagram also shows the primary outputs for each phase. There will be some difference in the implementation of this approach for each of the three types of scenario planning: predictive, normative, and exploratory. The unique aspects of these three types will be highlighted in the explanation of each phase below.

²¹ U.S. Department of Transportation, Federal Highway Administration, *Scenario Planning Guidebook*, 2011. Available at: http://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/scenario_planning_guidebook/.



Figure 4. Diagram. The Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.

Phase by Phase: Process, Participants, and Outputs

The information below describes how each phase of scenario planning could be accomplished in the context of TSMO.

Phase 1. How Should We Get Started?

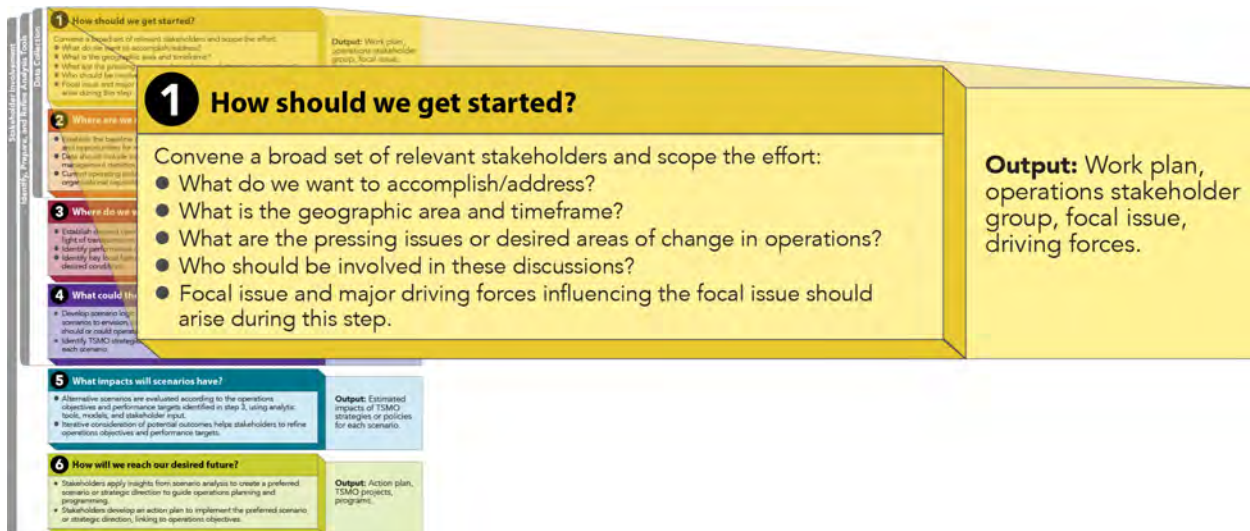


Figure 5. Diagram. Phase 1 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.

During this phase, the leaders of the scenario planning effort bring together a broad set of relevant stakeholders to scope the effort by answering questions such as:

- What do we want to accomplish or address?
- What is the geographic area (state, region, system, corridor)?
- What are the pressing issues or desired areas of change?
- Are there uncertainties we are concerned about?
- Who should be involved in this process, why, and how?
- What is our time horizon?

One of the perceived challenges of using scenario planning for TSMO is the inherent tension that exists in taking what is typically the shorter term (5-10 year time horizons) application of TSMO planning efforts, and expanding that view to allow for a longer term (20, 30 or 50+ year horizon) examination of potential futures. However, this perceived challenge is actually an opportunity to better define short-term, mid-term, and long-term TSMO strategies. It also helps create the foundation for TSMO implementation and monitoring to track progress against short- and long-term performance objectives.

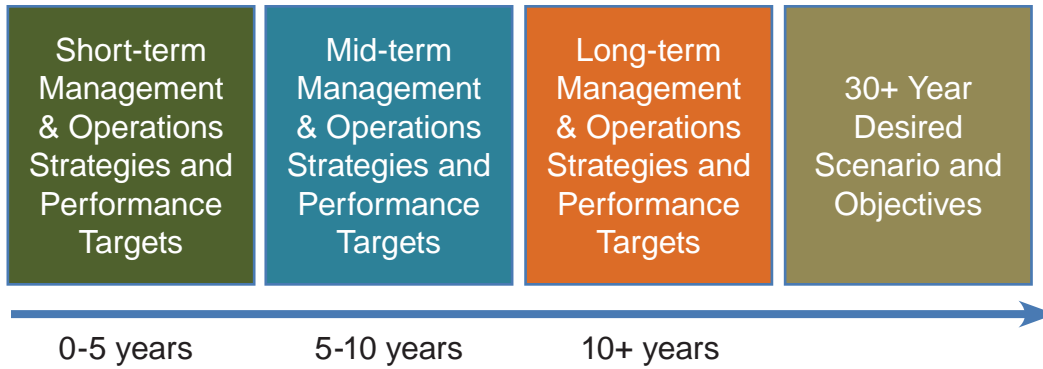


Figure 6. Diagram. Planning Horizons.

A critical activity during this phase is to pinpoint the specific questions and desired outcomes that stakeholders want the scenario planning effort to address. Identifying the target questions will help the project leaders to select the type of process best suited to their needs, as shown in Table 3.

Table 3. Scenario Planning Focal Questions and Outcomes.

Scenario Planning Type	Example Focal Questions	Outcomes and Benefits
<p>Predictive</p> <ul style="list-style-type: none"> • Look at scenarios in response to probable or likely trends. • The intent is to identify TSMO packages that are effective in light of probable trends of interest. 	<p>What are the most cost-effective TSMO strategies to support greenhouse gas emission targets given the potential impacts of a proposed new freight distribution center?</p>	<p>Aids in strengthening and sharpening the effectiveness of an existing plan or program by considering potential obstacles, opportunities, or changes in local conditions that could realistically emerge during the given time horizon. Typically used when wanting to test the effectiveness of a plan and/or to develop a “Plan B” to keep on hand in case the anticipated event or shift occurs.</p>
<p>Normative</p> <ul style="list-style-type: none"> • Examine scenarios depicting desirable future conditions. • The purpose is to build consensus on a preferred future and identify what is necessary to achieve that future (e.g., policy changes, operations objectives, TSMO investments, etc.). 	<p>How can TSMO policies and investments help the region to transform a congested, automobile-oriented suburban arterial corridor into a vibrant “Main Street” that provides safe, convenient accessibility for pedestrians, bicyclists, bus riders, car drivers, and commercial truck drivers?</p>	<p>Helps to reach consensus on a clearly defined, shared vision, goals, and strategies. This is beneficial when there is no clear vision to guide decisions, when different stakeholders have competing visions, or when a shift in policy triggers the need to redefine the vision. Typically used when wanting to articulate, reconcile, or reconsider the definition of a “desirable” future.</p>
<p>Exploratory</p> <ul style="list-style-type: none"> • Investigate different scenarios in response to uncontrollable and unknown future conditions. • The goal is to identify plans, policies, strategies that work best in all conditions. 	<p>How can the region best prepare to maintain transportation system efficiency and reliability in light of the various potential environmental changes that may occur over time due to the impacts of climate change?</p>	<p>Facilitates planning for resiliency in response to uncertainty. Also within this category is the benefit of managing risks due to uncertainty (i.e., deciding how to invest in ITS/TMCs based on uncertain technology trends.) Scenario planning can help communities arrive at decisions about operations made in the context of very different assumptions regarding future events, trends, policies, priorities, or other factors of uncertainty.</p>

ITS = intelligent transportation systems
TMC = traffic management center
TSMO = transportation systems management and operations

In order to garner broad discussions, the leaders of a TSMO scenario planning activity, regardless of type, should engage a diverse stakeholder group in the process that reflects interests and expertise across disciplines. This group will help to confirm trends and factors that may influence those trends. This will in turn confirm the overall aspirations of the stakeholders and support the effort to develop strategies.

This could include operators; transportation, land-use, and housing planners; emergency management professionals; traffic reporters; public information officers; local developers; demographers; communications and information technology experts; economic development officials; and representatives from State, city, and county departments of transportation (DOT); public works departments; transit agencies; port authorities; toll authorities or high-occupancy toll (HOT) lane operators; pedestrian and bicycle groups; disability advocacy organizations; universities; the trucking, rail, and port industry; and the private sector. The stakeholders that may be involved vary depending on the purpose of the TSMO planning activity. For TSMO planning activities focused on traffic incident management or emergency transportation operations, emergency management agencies and public safety organizations such as State and local police, fire/emergency medical services (EMS), towing, hazardous materials (HAZMAT) responders, and 911 operators should be considered. During Phase 1, additional stakeholders will likely be identified and invited to be part of the effort.

Stakeholder identification can build upon the existing public outreach plans of the metropolitan planning organization (MPO), which often includes standing committees or stakeholder groups that are regularly engaged in long-range transportation planning or other cross-agency planning efforts within the region. For instance, many MPOs have a standing land-use committee to aid in the development of long-term socioeconomic forecasts; in addition, many communities also have identified cross-agency representatives for emergency operations planning that could also be easily identified.

Phase 2. Where Are We Now?

At this stage it is important to gather the baseline information that will provide relevant context to help answer the target questions. This will likely include data for past trends, current conditions, and projected future trends that build off of the existing information in metropolitan or statewide transportation plans and records of travel conditions maintained by a transportation management center (TMC), DOT, or transit operating agency. If trying to conduct scenario planning to address extreme weather or climate change, it would be important to gather conditions and trends relative to transportation system performance under previous disruptions as well as information on future weather trends. Typically, TSMO-oriented scenario planning groups would gather transportation data needed to identify 10-year and 20-year trends and

issues along with opportunities in growth and development. This may include travel demand, truck traffic, port use, transit ridership, and other information that may provide insights into travel demand, economic drivers, and other important factors that could influence system-wide transportation dynamics.



Figure 7. Diagram. Phase 2 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.

The purpose of this initial data gathering effort is to understand the operations context in terms of future trends and how that relates to the questions of interest. For instance, questions that the stakeholders may want to answer through data gathering during this phase include:

- How much time do people spend traveling today and what is it projected to be in the future?
- How much additional time is required when operating conditions are affected by weather, incidents, or special events? Has advanced planning taken place to ensure a minimum of disruption during such events?
- Is access to destinations by walking, biking or taking transit adequately incorporated into the transportation system?
- What are the projected increases in travel-inducing development and how is travel adaptation to growth being addressed in the corridor or across the region?
- What are the current levels of greenhouse gas (GHG) emissions per capita in the region?

This baseline data can come from sources and analysis associated with regional travel demand models, geographic information system (GIS) analysis of accessibility, and archived operations data. In addition, trends in technology use by operators and travelers should be considered for building scenarios in the next phases. This baseline information should also include the current operating and institutional policies for the region, corridor, or area of focus.

It is also important to bring to any scenario planning effort the overall goals that are part of current, overarching documents such as the metropolitan transportation plan (MTP) or statewide long-range transportation plan. Long-range transportation plan goals would be a reasonable starting point for initiating discussions about operational goals and fostering more dialogue about how the transportation system ultimately can support a community’s desired future.

In addition, if the scenario process is exploratory, it may be helpful at this stage to discuss reasonable goals and expectations about how the transportation system ideally would function in response to specific events or weather occurrences. These goal-setting discussions set the context for the scenario planning effort. During this phase, it is important either to reaffirm existing goals or to identify new goals that can drive scenario development.

Phase 3. Where Do We Want To Go?

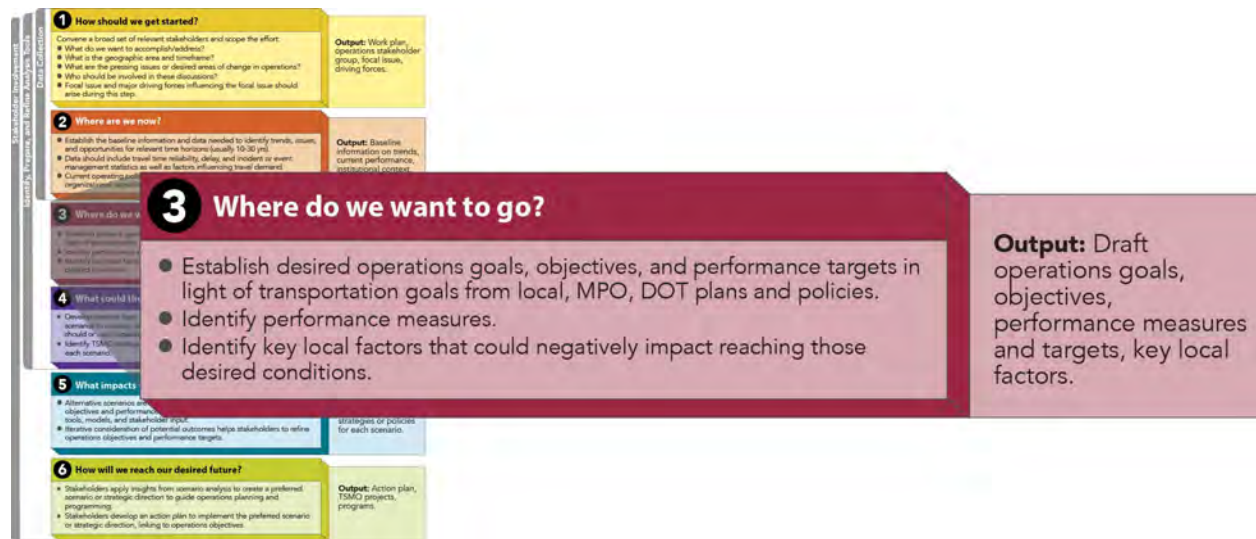


Figure 8. Diagram. Phase 3 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.

With a solid understanding of the existing operations context and likely future trends, the next phase involves discussing and identifying specific operations goals and objectives for the transportation system. These discussions should be geared towards developing goals that describe different quality of life or value-oriented outcomes such as “we want to spend less time driving alone in our cars to meet our daily travel needs,” or “we want to spend less time sitting in congestion,” or “we want travelers to have all necessary information on travel time, mode, and costs in real-time to make better travel decisions,” or “we want more reliable, comfortable, and healthy options for getting to and from work,” or “we want to create a transportation system that helps reduce greenhouse gas emissions.”

To foster the discussion, stakeholders might pose some of the following questions to help identify goals and desired outcomes:

- What is working well today, and how might that work in the future given projected changes in demand, development, vehicle or infrastructure technology, policies, or funding levels?

Scenario Planning Adds Value

One of the valued-added elements of using scenario planning to establish operations goals and objectives is that it can foster the discussion of operations objectives that can be both supported by transportation systems management and operations (TSMO) strategies as well as prompt development of a more holistic set of strategies across different sectors or implementing agencies.

For instance, if the objective is to increase efficiency in non-single-occupancy-vehicle (SOV) trips, there may be a bundle of strategies that can be used to effect that change, such as travel demand management, transit signal prioritization, local land-use policy changes, bus operational improvements or service expansions, improvements to bicycle and pedestrian infrastructure, congestion pricing, and place-based employer recruitment.

Engaging representatives from different agencies in these early goal- and objective-setting conversations helps all parties better understand the relationships between different variables across community systems, revealing the interrelated nature of land use, transportation, economic development and resource protection.

- Are there competing interests relative to mobility and accessibility?
- Are there regional or local transportation goals to shift more people into non-motorized or shared-use modes of transportation?
- If so, what kind of transit reliability and service is most desirable?
- What level of additional cargo and associated businesses is the community trying to accommodate or attract?
- Are there specific concerns about reducing overall vehicle miles traveled (VMT) or reducing peak hour levels of congestion on certain corridors?
- What is a reasonable expectation of system functioning under extreme weather events?

At this phase, an important outcome is to start to identify some very concrete goals and objectives from which more specific operations objectives and performances measures can be developed and used to evaluate different scenarios and ultimately monitor system performance over time. This discussion should remain high-level in nature to ensure that the view points of the various stakeholders are reflected, but it should also be specific enough to generate ideas about operations objectives.

Translating these goals into operations objectives using scenario planning requires an iterative approach. After identifying goals and understanding current conditions and trends, stakeholders could begin to identify their desired outcome-based

objectives for operations. At this stage, it is unlikely that the stakeholders would identify specific targets for those objectives. Instead, it is anticipated that stakeholders would identify the aspect of performance they would like to see changed, such as “improve bus on-time performance,” “increase travel time reliability on arterials or a specific corridor” or “less stressful trips for trucks carrying goods into the city center.” The identification of these initial objectives should also lead to the development of performance measures that will be used in the evaluation and comparison of scenarios. For example, performance measures corresponding to the objectives

could include “buffer time index,” “total average truck trip time into and out of the city center,” and “bus on-time performance.”

During the stakeholder conversations of this stage, the TSMO planning leaders can work to identify performance measures iteratively with the stakeholder group. Brainstorming the range of TSMO objectives and performance measures at this stage can help to better anticipate the full spectrum of objectives that can drive the creation of scenarios. Operations objectives and performance measures can be adapted from the FHWA *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*.²²

Phase 4. What Could the Future Look Like?

In this phase, the scenario planning leaders work with the stakeholders to develop distinct scenarios that describe a potential future for how the transportation system may function (from Phase 1) and the TSMO strategies and other solutions to achieve the community’s goals and objectives (from Phase 3) given the scenario description.



Figure 9. Diagram. Phase 4 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.

The development of the scenarios during this phase is the most critical piece of the scenario planning approach and will likely require the most effort of any phase. Before creating the scenarios, it is important to keep in mind that the resulting set of scenarios should:

- Help participants consider the most important “what-ifs” of the focal question.
- Represent a range of plausible alternative futures (not forecasts).
- Be at least three in number (some experts recommend three to five scenarios as the optimal number).

²² U.S. Department of Transportation, Federal Highway Administration, *Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations - A Desk Reference*, FHWA-HOP-10-027 (Washington, DC: FHWA, 2010). Available at: <http://www.ops.fhwa.dot.gov/publications/fhwahop10027/>.

- Not represent obviously good or bad scenarios that would limit exploration and discussion.

This section will take the reader step-by-step through the development of a set of scenarios. These steps developed by Peter Schwartz in *The Art of the Long View* complement the FHWA scenario-planning framework, and expand upon Phase 4’s scenario development task.²³

Step 1. Identify Focal Issue. This is the central question (identified in Phase 1) to be answered. For example, “How should this corridor function in the region?”, “How do we improve the reliability of the region’s arterial network?”, or “What TSMO strategies should we use to improve system performance under different extreme weather events?” During this phase, the scenario planning leaders should confirm the central question with the stakeholders and see if any revisions are needed based on the work in Phases 2 and 3.

Sample Driving Forces for Exploratory TSMO Scenarios

Rise in Oil Prices may lead to greater use of car sharing programs or reduced travel demand.

Climate Change may lead to an increase in evacuations and need for alternative routes in cases of flooding.

An Influx of Millennials who do not own vehicles into urban centers may lead to greater demand for transit, walking, and bicycling.

Move toward Connected Cities may lead to greater opportunities to support travel on demand regardless of mode.

Connected and Autonomous Vehicles may have major impacts on all traffic management activities including traffic incident management, access management, and intersection control.

Step 2. Identify Key Local Factors. These are the factors that influence the success of addressing the focal issue. They can be considered key influencing factors and they typically relate to the stakeholders of the scenario planning effort. These should be considered when creating the details of the scenarios. For example, a key local factor could be that hurricane evacuations in the region have been under intense scrutiny ever since a difficult evacuation in the past year. Another key local factor could be the available funding for transportation operations or a push by a prominent organization for cleaner transportation alternatives. Key local factors should be identified from the discussions in Phases 2 and 3, where relevant contextual information is gathered and stakeholder goals and objectives are voiced and debated. It will be helpful during this phase to confirm the local factors with stakeholders.

Step 3. Identify Driving Forces. These are the major and typically high-level influences on the focal issue that are not controlled by those involved

in the scenario planning. This includes uncertain trends or events such as climate change, gas prices, unemployment levels, or terrorist attacks. Uncertainty as a driving force is particularly true in the exploratory typology of scenario planning. In the normative or predictive typologies, driving forces are likely to include differing priorities or opposing visions for the operation of a transportation system or facility. The driving forces should surface in Phase 1 of the scenario planning process during the discussion of pressing issues and then be further specified in Phases 2 and 3 during the discussion of contextual information, goals, and operations objectives.

²³ Peter Schwartz, *The Art of the Long View* (New York, NY: Currency Doubleday, 1991).

Step 4. Rank Driving Forces by Importance and Uncertainty. During this step, the scenario planning leaders and stakeholder prioritize the driving forces by importance and, in the case of exploratory scenario planning, uncertainty. This activity is critical to identifying those forces that will shape the scenarios. Those forces that are both highly important and uncertain should be considered as drivers for developing the scenarios. The driving forces may be identified from a range of factors that impact transportation outcomes: social, technological, economic, environmental, and political.²⁴

Step 5. Select Scenario Logic. This is the step that specifies the rationale and structure for how the scenarios will be built. The “scenario logic” is the set of the most important driving forces and the different values those forces will take in the scenarios. For instance, Table 4 shows the simple scenario logic for a scenario planning effort that aims to prepare TSMO activities and programs for the impacts of climate change. In this example, there are two driving forces whose impacts vary by frequency.

Table 4. Example Driving Forces to Shape Scenario Logic.

Levels of Carless Households in Dense Urban Area	Hurricane Force Winds and Flooding	
	Frequent hurricane force winds and flooding (\geq four times/year)	Infrequent hurricane force winds/flooding (\leq once every 3 years)
High levels of carless households (40% or more) due to aging population and preferences for car-free lifestyle among Millennials.	Scenario A: Frequent road flooding and hurricane force winds and high levels of carless households.	Scenario B: Infrequent hurricane force winds and flooding with high levels of carless households.
Low levels of carless households.	Scenario C: Frequent flooding and hurricane force winds with low levels of carless households.	Scenario D: Infrequent flooding and hurricane force winds with low levels of carless households.

Step 6. Flesh Out the Scenarios. In this last step of scenario creation, less critical factors and local influences are used to expand the scenario descriptions so that they are more realistic and contain crucial information on how other important factors or influences come to fruition or fade away in the future. The scenarios should be plausible and internally consistent once they are finished.

Following the development of the scenarios, management and operations experts must identify the TSMO strategies that are necessary to optimize the goals for each potential future. Adequate detail is needed to analyze the potential costs and strategy impacts on the identified performance measures. Once a broad set of scenario stories are established and some specific goals and objectives are identified, different packages of TSMO strategies can be created. Depending on

²⁴ Peter Schwartz, *The Art of the Long View* (New York, NY: Currency Doubleday, 1991).

the nature of the scenario approach or process, these could be system-wide strategies or corridor-specific strategies. In the case of longer term scenario planning for operations, the set of TSMO strategies should reflect some notion of a tiered timeline as noted in Figure 6.

Phase 5. What Impacts Will Scenarios Have?

Once strategies are identified for each scenario, analysis and modeling should be conducted to the extent possible to quantify the relative benefits or impacts of those different strategies on achieving near-term and long-term objectives. The analysis can be conducted using a combination of scenario planning tools combined with either data inputs and outputs or assumptions garnered from sketch planning tools focused on TSMO, such as the Tool for Operations Benefit Cost Analysis (TOPS-BC) developed by FHWA.²⁵



Figure 10. Diagram. Phase 5 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.

The scenarios are also assessed against the other, broader goals of the region or area of focus: travel options, air quality, economy, commerce, and safety. During this step, the stakeholders are engaged to provide qualitative assessment information with regard to the goals to supplement and consider the quantitative outputs that are available, which will also include discussions of the relative costs and benefits of the sets of strategies considered. It is during this evaluation phase that the tradeoff discussions concerning different strategies and objectives will occur.

Based on the evaluation of the scenarios' estimated effects on the performance metrics of interest and in reaching the operations objectives, the TSMO planners and stakeholders can go back and refine the operations objectives to more realistically match potential outcomes. Following this work, the participants in the process should collaboratively decide on a preferred scenario or set of strategies from multiple scenarios that can be used for guiding operations-related planning and, ultimately, project selection and investment decisions.

²⁵ U.S. Department of Transportation, Federal Highway Administration, "Tool for Operations Benefit Cost Analysis" (TOPS-BC), Web site. Available at: <http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm>.

Phase 6. How Will We Reach Our Desired Future?

Once there is consensus on a preferred scenario or set of strategies, the TSMO planners should develop the more detailed plans and packages of strategies that will serve as the basis for a corridor or network operations plan. This should include work to create an action plan for actualizing the scenario in terms of new projects and investments, policy changes, institutional arrangements, and a plan for measuring progress. The scenario planning process will help planners and operators hone in on the key performance measures and objectives that will drive the final planning and implementation process. It is those same measures and objectives that will also inform regular monitoring of advances toward meeting short-term and long-term objectives.



Figure 11. Diagram. Phase 6 of the Federal Highway Administration Scenario Planning Framework Adapted to Transportation Systems Management and Operations.

Analysis Tools and Data to Support Scenario Planning for Transportation Systems Management and Operations

Analytical tools, models, and archived data provide an important foundation to support scenario planning. Analytics, visualizations, and the underlying data are critical in presenting the stories in scenarios and highlighting the key variables or differences between different futures. Baseline data is needed to answer the “where are we now” question in Phase 2 of the scenario planning process. The purpose of analytics in scenario testing is to support the development of plausible future conditions and illustrate the key features and performance of each scenario so that stakeholders can clearly understand the differences and impacts between them. Analysis and visualization tools to support scenario planning for TSMO are really no different than the array of tools used to conduct traditional travel analysis. The data development and analysis steps should be calibrated to help inform the decisionmaking process as opposed to predictive models of the future.

Tools relevant for scenario planning in the context of TSMO can be obtained from the suite of tools used for transportation system planning, policy, implementation, and operations analyses. In general, all transportation analysis tools follow a general flow of information and analysis explaining how:

- Land-use and network characteristics affect travel behavior.
- Travel behavior affects travel demand.
- Travel demand affects multimodal management and operations.

The analytical framework for transportation varies most often to reflect different geographic scales and time horizons (e.g., from regional econometrics explained on an annual or quarterly scale through block-level travel behavior for typical lane-specific data assessed on a minute-by-minute basis). The relationships between travel behavior, travel demand, and system operations can be examined and explored through scenario planning processes. For example, when and how to implement value pricing by time of day or level of demand, by geographic location (e.g., a cordon pricing tool), and by travel market (e.g., comparing HOT lanes to Express Toll Lanes or influencing freight flows by axle or weigh-in-motion pricing) will have a significant impact on travel behavior and vice versa.

The selection of an analytical framework and tools to support scenario planning for TSMO should be derived from the key questions and driving forces identified in the early scoping efforts. Developing the analytical framework requires the selection of tools most appropriate for the scale at which measures of effectiveness are desired and the appropriate feedback loop can be assessed. The choice of tools and level of analysis should also reflect consideration of the time and effort required to develop baseline information and create plausible future conditions. TSMO planners may find it helpful to access empirical research and other information to develop some key assumptions about hypothetical future conditions as it relates to traveler behavior, climate change, autonomous vehicles, or other factors. Being transparent and documenting those key assumptions and sharing them with stakeholders is an important step in building confidence in the validity of scenario comparisons and tradeoff discussions.

There may also be some limitations with the current palette of tools available to support scenario planning and analysis within a TSMO context. In particular, there are few standard methodologies for developing future forecasts for performance metrics related to TSMO, such as reliability. Also, the current set of tools supporting travel demand analysis does not yet adequately reflect sensitivity to the influences of development patterns and infrastructure design on multimodal traveler behavior. Therefore, for any given TSMO scenario planning effort, there may be a need for new and creative approaches to utilizing existing data and tools to serve the scenario planning process.

Given the history of scenario planning in transportation, many of the common transportation scenario planning tools focus on estimating and comparing the effects that different land-use scenarios have on transportation (and vice versa), as well as on performance metrics related to the economy, environment, and other outcomes. Over the last decade several stand-alone software packages have emerged and are available to practitioners to simplify the process of developing

and comparing land-use scenarios across a broad range of performance metrics. Some of the more commonly used land-use planning tools include software packages such as CommunityViz, Envision, and the Land Use and Transportation Scenario Analysis and Microsimulation (LUTSAM) Tool. While these tools can be helpful to TSMO-based planning efforts that seek to examine different travel demand dynamics influenced by the built environment, this suite of tools will likely need to be supplemented to incorporate more common TSMO measures of effectiveness.

The primary goal of the analytical framework for scenario testing is to demonstrate how various factors affect overall outcomes—whether or not desirable outcomes can be attained. This testing can illuminate the effects different variables have on travel outcomes within and between scenarios. A multi-scenario method may be developed and applied on top of any of the traditional analysis tools so as to evaluate TSMO strategies in several different conditions. Weather conditions, incidents, work zones, and other system variations may be represented by altering baseline conditions.²⁶ Multiscenario methods have been incorporated into advanced analysis, modeling, and simulation systems to evaluate integrated corridor management (ICM) approaches on reliability metrics.

Travel demand models may be most applicable to TSMO scenario planning efforts at the regional level where analysis results are focused on evaluating how different economic, land-use, and demographic variables may influence travel demand and thereby influence system-level TSMO strategies. For instance, if one of the key questions driving the scenario development is the potential impact of long-term changes in travel behavior of aging populations and millennials, then the use of a travel demand model complemented by additional GIS-based multimodal accessibility analysis may be helpful. Archived operations data can be used to support other analysis methods with input data, calibration, and validation. This information plays an important role in understanding current performance of the transportation system. Simulation models or traffic signal optimization tools may be helpful when looking at a smaller area of influence where scenario testing is being performed at a fine-grained level of detail concerning system operations. For example, a scenario planning process may be desirable to better understand the impacts on vehicular mobility if traffic signals are prioritized to give “green time” to pedestrian and bicycle movements rather than motorized vehicles.

The following provides a summary of the different types of tools that may be used to support scenario planning for TSMO. These can vary in purpose, complexity, input and output data, strategies analyzed, expertise required, and cost. The current methods and tools can generally be grouped into the following categories:

- Archived operations data.
- Travel demand models.
- Sketch planning tools.

²⁶ A. Vandervalk, H. Louch, J. Guerre, and R. Margiotta, *Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes: Technical Reference*, Transportation Research Board of the National Academies, Project S2-L05-RR-3 (Washington, DC: TRB: 2014). Available at: <http://www.trb.org/Main/Blurbs/168856.aspx>.

- Visualization tools.
- Analytical/deterministic tools (based on the Highway Capacity Manual (HCM)).
- Simulation models.
- Traffic signal optimization tools.
- Many hybrid approaches of all the above.

Archived Operations Data

Archived operations data is data that is collected and stored to support the monitoring and management of the transportation system. This includes traffic, transit, bike, pedestrian, construction, and weather information that are usually collected in real time by ITS and other technologies.

The following are some examples:

- Traffic volume, speed, class, or occupancy from point and probe data sources (e.g., National Performance Management Research Data Set (NPMRDS)).
- Origin-destination (OD) data.
- Public safety computer-aided dispatch (CAD) information.
- Surveillance video, automatic vehicle location (AVL), signal status, event and weather information.

As mentioned above, archived operations data is plentiful in many regions and can be used in *Phase 2: Where Are We Now?* to document baseline operational conditions and to identify and report performance issues or needs. This data allows planners to investigate causes of congestion by correlating multiple data sets over time and analyzing event-related traffic flows and weather impacts. In addition, knowing the current level of performance for the transportation area of interest is necessary for setting realistic performance objectives (or targets) in *Phase 3 Where Do We Want to Go?* This information will also be helpful in identifying the key variables necessary to consider for TSMO when developing future scenarios.

Travel Demand Models

Travel demand models are widely used for estimating changes in mode choice and traffic patterns and volumes due to changes in development levels, demographics, and the transportation system (road and transit). These tools are important in scenario planning for TSMO in screening strategies applied on a regional or corridor scale. They can also supply data to sketch-planning tools and simulation models that can further analyze TSMO strategies. The three- and four-step travel demand models are fairly limited in their ability to analyze TSMO strategies or reflect mode choice sensitivity at the urban scale, but activity-based travel demand models can evaluate a wider range of operations-related strategies that may be part of a scenario, including pricing strategies, travel demand management programs, and other TSMO strategies with a detailed network model. Activity-based models require a greater investment of time and resources than traditional travel demand models. Travel demand models can support scenario analysis in

Phase 5. What Impacts Will Scenarios Have? as well as help planners and other stakeholders understand future trends identified in *Phase 2. Where Are We Now?*

Sketch Planning Tools

Sketch planning tools are often the easiest to use for obtaining a quick, rough estimate of how the TSMO strategies that support a scenario compare in terms of benefits against those strategies of other scenarios. These are low-cost tools that help “sketch” a big picture, but they can be limited when seeking a fine-grained level of analysis. Sketch planning tools provide order of magnitude estimates with minimal input data in support of preliminary screening assessments. The tools are often spreadsheets or simple databases with built-in assumptions derived from empirical research as to the impacts or benefits of applying various strategies. Examples include TOPS-BC, California Life-Cycle Benefit/Cost Analysis Model (Cal B/C), Screening Tool for ITS (SCRITS), and QuickZone. Some sketch planning tools integrate with a travel demand model and provide data post-processing to facilitate the review of TSMO strategies and can also be linked up with visualization modules.

Visualization Tools

Visualization tools reflect the broad category of methods that support the creation of maps, three-dimensional (3-D) illustrations, and graphic imagery based products aimed at visually highlighting the differences assumed in each scenario. Depending on the key driving issues, the visualizations may be focused on preparing 3-D graphics to demonstrate imagery of the built form. GIS-based mapping may also be helpful in highlighting different place-based variables of relevance in terms of the location of different transportation solutions, impacts of sea-level rise, variances in travel demand, etc. Visualization methods are most often linked with the outputs of other analytic tools and can be extremely valuable in helping to communicate the key issues to a wide range of stakeholders.

Analytical/Deterministic Tools (Highway Capacity Model-based)

This category of tools implements the procedures outlined in the HCM. The tools are static in that they predict average operating conditions over a fixed time period (e.g., a 15-minute or 1-hour period) and do not deal with transitions in operations from one system state to another. They are currently used most often to predict capacity, density, speed, delay, and queuing on a variety of transportation facilities. Examples include Highway Capacity Software (HCS) and Traffix. These tools may provide some value to TSMO scenario planning when the geographic scale is small and the desired granularity of operational conditions warrants evaluation at the individual intersection or facility scale to assess the impacts of different traffic control strategies (e.g. uncontrolled, stop-controlled, or signalized intersections). Outputs associated with different scenarios could be fed into the HCM model to evaluate relative impacts and sensitivity to different conditions.

Simulation Models

This category of tools represents transportation system operations by using a variety of formulas and algorithms to simulate travel behavior. They can be applied to isolated locations, corridors,

and area-wide conditions. Many include environmental outputs (e.g., emissions) and some models now also include multimodal considerations. Simulation models generally fall within three different categories:

- **Macroscopic:** Simulates average flow, speed, and density on a segment-by-segment basis.
- **Mesoscopic:** Simulates individual vehicles based on average segment speed and density.
- **Microscopic:** Simulates detailed movement of individual vehicles throughout the network.

These models are typically used to evaluate a range of improvements and strategies at local or corridor levels. They can be used to test variability in traffic demand or incident severity and also include visualization. These tools may be helpful in scenario testing; however, they do require specialized expertise and software, which can increase the level of effort and cost associated with the testing.

Traffic Signal Optimization Tools

Similar to analytical/deterministic tools, traffic optimization tool methodologies are mostly based on the HCM procedures and are used to analyze delay and identify optimum signal phasing and timing plans for isolated intersections, arterial streets, or signal networks. They may include capacity calculations; cycle length; splits optimization, including left turns; and coordination/offset plans. The type of signal optimization tool used is best determined based on the goal of the traffic signal timing study, network conditions, and data availability. Similarly, these tools may prove valuable during the scenario testing phase if the focus of the problem warrants this level of detail.

Any of the tools described above may be utilized to respond to the questions unique to the TSMO environment, with a more micro-scale approach appropriate for TSMO project applications and a macro-scale approach applied for TSMO policy and planning considerations. For example:

- A microscopic simulation model might be appropriate to consider a policy of adapting signal timing plans in an urban central business district to accommodate pedestrian crossings with fully exclusive pedestrian phases at 2.5 feet per second as opposed to a mix of exclusive and permitted phases at 3.5 feet per second. A feedback loop might be applied in a regional travel demand model by assigning an implicit capacity penalty to urban streets if the same scenario were to be examined regionally.
- A travel demand model might be appropriate to consider the effects of alternative congestion or parking pricing schemes in a multimodal corridor. A feedback loop might be tested in a sketch planning tool to examine similar pricing schemes from a regional or statewide perspective.

As with any analytical framework to support transportation decisionmaking, the key is to select the right tool for the problem at hand and give thought to the level of effort, resources, and time available.

Section 4: Opportunities for Scenario Planning to Advance Transportation Systems Management and Operations

Planning for transportation systems management and operations (TSMO) occurs both formally and informally at the statewide, regional, subarea, local, corridor, project, and multi-state level. Scenario planning is a tool that planners and operators can apply in all of those contexts to prepare for uncertainty, resolve competing visions, create more robust stakeholder engagement opportunities, and better align an area's transportation goals with TSMO strategies. As previously noted, the type of scenario planning to be applied depends on the focal questions and desired outcomes of the stakeholders. The purpose of this section is to explore the many opportunities available to use each type of scenario planning to advance TSMO. This section describes how scenario planning for TSMO can be applied at the metropolitan, statewide, and corridor levels as well as how it can be applied to TSMO planning motivated by possible future events or emerging trends.

Integrating Transportation Systems Management and Operations into the Metropolitan Transportation Plan

Many metropolitan planning organizations (MPO) already include transportation systems management and operations (TSMO) strategies in their long-range transportation plans (LRTP). This can include identifying corridors of regional significance where new intelligent transportation system (ITS) infrastructure is being targeted or developing broader policies aimed at creating a more robust transportation demand management (TDM) program for a given region. TSMO strategies have also been included as components of scenario planning efforts to develop LRTPs.

In some regions the performance metrics are changing—no longer is auto mobility the primary goal; instead, many communities are looking at new measures such as multimodal accessibility or person throughput across the network. As such, the transportation planning challenges are shifting in response to efforts to accommodate more modes (walking, biking, transit, high-occupancy vehicle (HOV)) within existing rights of way. In effect, shifting an auto-oriented corridor to a more multimodal corridor is at its essence a system preservation strategy.

When regions are planning for the long term, there is a huge opportunity to bring TSMO considerations into the conversation in an effort to look at the full range of both design as well as management and operations (M&O) strategies to help support the community's objectives. Simply having the TSMO planners as part of the conversation early on can help in the design of scenarios and can also help with the longer term TSMO planning.

The following sections highlight some of the opportunities to improve TSMO through the use of scenario planning.

Regional Opportunities

At the regional level, planning for TSMO is often led by the metropolitan planning organization (MPO), which convenes a group of TSMO stakeholders to advance TSMO in the region. Typically, planning occurs in coordination with the development of the metropolitan transportation plan as a means of including TSMO priorities and strategies into the overall metropolitan transportation plan (MTP) and including TSMO programs and projects in the transportation improvement program (TIP). Planning for TSMO at the regional level may also be led by a coalition of operating agencies or a State department of transportation (DOT) district. For the purposes of this primer, a region does not need to coincide with an MPO boundary, but instead can be any multi-jurisdictional area as defined by the TSMO partners. A regional operations plan, intelligent transportation systems (ITS) strategic plan, or regional concept for transportation operations (RCTO)²⁷ are all products that may be developed as a result of planning for TSMO at the regional level. The opportunity to use scenario planning to advance TSMO at the regional level exists in the development of these products as well as in the process of planning for TSMO as an integrated component of the overarching metropolitan transportation planning process.

Developing Operations Objectives for a Regional Operations Plan

A regional operations plan is a generic term for a multi-jurisdictional, multi-agency plan that describes what the region's stakeholders have agreed to achieve in terms of operational performance of the transportation system (or element) and how they will reach those goals and objectives. This includes regional concepts for transportation operations and many ITS strategic plans. Scenario planning can be used to identify and reach consensus on many of the elements of a regional operations plan. For example, by applying a normative type of scenario planning, the stakeholders explore and decide on a preferred set of operations objectives. If there were differing ideas of which operations objectives should be selected to guide their work toward advancing TSMO in their region, the stakeholders could build scenarios that portray how the future transportation system would function if each set of operations objectives was reached. They would then look at what kinds of TSMO strategies would be necessary for those scenarios to be realized and analyze and compare the implications of those scenarios. Using scenarios will lead the stakeholders through a discussion of their priorities and whether reaching a given set of operations objectives is feasible. The operations objectives developed for the regional operations plan can be used as input to the MTP's goals and objectives.

Table 5 provides sample operations objectives that can be tailored for use in a scenario planning exercise for a regional operations plan or many other TSMO planning activities.

²⁷ Learn more about a regional concept of transportation operations at the FHWA Regional Concept for Transportation Operations (RCTO) web page. Available at: http://www.ops.fhwa.dot.gov/plan4ops/focus_areas/trans_ops.htm.

Table 5. Sample Operations Objectives for Use in Scenario Planning.

System Efficiency	
Vehicle Miles Traveled	<ul style="list-style-type: none"> • Reduce vehicle miles traveled per capita by X percent by year Y.
Trip Connectivity	<ul style="list-style-type: none"> • Reduce door-to-door trip time by X percent by year Y.
Duration of Congestion	<ul style="list-style-type: none"> • Reduce the daily hours of recurring congestion on major highways from X to Y by year Z.
Energy Consumption	<ul style="list-style-type: none"> • Reduce total energy consumption per capita for transportation by X percent by year Y. • Reduce total fuel consumption per capita for transportation by X percent by year Y. • Reduce excess fuel consumed due to congestion by X percent by 2020.
System Reliability	
Non-Recurring Delay	<ul style="list-style-type: none"> • Reduce total person hours of delay (or travel time delay per capita) by time period (peak, off-peak) caused by: <ul style="list-style-type: none"> • (Option 1) scheduled events, work zones, or system maintenance by X hours in Y years. • (Option 2) unscheduled disruptions to travel. • (Option 3) all transient events such as traffic incidents, special events, and work zones.
Travel Time Buffer Index	<ul style="list-style-type: none"> • Decrease the buffer index for (specific travel routes) by X percent over the next Y years. • Decrease the average buffer index for (multiple routes or trips) by X percent over Y years. • Reduce the average buffer time needed to arrive on-time for 95 percent of trips on (specified routes) by X minutes over Y years.
Planning Time Index	<ul style="list-style-type: none"> • Reduce the average planning time index for (specific routes in region) by X (no units) over the next Y years. • Reduce the average planning time for (specific routes in region) by X minutes over the next Y years.
Travel Time 95th/90th Percentile	<ul style="list-style-type: none"> • Reduce the average of the 90th (or 95th) percentile travel times for (a group of specific travel routes or trips in the region) by X minutes in Y years. • Reduce the 90th (or 95th) percentile travel times for each route selected by X percent over Y years.
Variability	<ul style="list-style-type: none"> • Reduce the variability of travel time on specified routes by X percent during peak and off-peak periods by year Y.
Transit On-time Performance	<ul style="list-style-type: none"> • Improve average on-time performance for specified transit routes/ facilities by X percent within Y years.

Table 5. Sample Operations Objectives for Use in Scenario Planning. (Continued)

System Options	
Mode Share	<ul style="list-style-type: none"> • Reduce per capita single-occupancy vehicle (SOV) commute trip rate by X percent in Y years. • Increase alternative (non-SOV) mode share for all trips by X percent within the next Y years. • Increase active (bicycle/pedestrian) mode share by X percent by year Y. • Reduce SOV vehicle trips by X percent through travel demand management strategies (e.g., employer or residential rideshare) by year Y. • Achieve X percent alternative (non-SOV) mode share in transit station communities (or other destinations) by year Y.

Developing the Approach for a Regional Concept for Transportation Operations

Alternatively, scenario planning can be applied to help identify the “how” of an operations plan or RCTO including the TSMO strategies. For example, the RCTO developers could use scenario planning to identify a set of TSMO strategies that would be most effective given uncertainty about whether and exactly where a light rail system will be built in the next 10 years in the region. An exploratory type of scenario planning would facilitate a discussion about how the region’s transportation system could function depending on the presence or absence of a new light rail system and which TSMO strategies would be most effective in all possible scenarios.

A predictive approach to scenario planning could also be used during the development of an RCTO approach. Stakeholders could use scenario planning to help examine how effective different TSMO strategies might be relative to assumptions concerning available funding or availability of new forms of data and real-time monitoring. This predictive approach to scenario planning assumes the major variables such as travel demand and travel behavior follow a predictable pattern or forecast, but there may be variability in funding or data availability. The purpose of this scenario planning exercise would be to identify which TSMO strategies will work best in managing system performance to achieve desirable goals over the RCTO’s time horizon.

Identifying Packages of Transportation Investments Including Operations for a Metropolitan Transportation Plan

Scenario planning could be used during the development of the MTP in response to a region’s desire to look at different alternatives for growth and development relative to achieving a distinct vision or specific goals, like reducing emissions or increasing transportation choices. Through a normative typology for scenario planning, the region’s stakeholders would develop multiple scenarios, including TSMO strategies at the system-level, based on different assumptions concerning future development patterns (land use) and packages of transportation capital

investments. TSMO stakeholders would be brought in to identify specific TSMO strategies that could support each scenario. The scenarios would be evaluated and considered by a broad stakeholder group for the purpose of achieving specific goals illustrated by specific performance measures, like reducing travel time for autos and transit or incorporating TDM strategies to reduce overall travel demand.

The participation of TSMO stakeholders and consideration of TSMO strategies at the long-term planning stage can lead to early identification of new data gathering and real-time system performance monitoring needs. These early conversations about scenarios also lay the groundwork for the more detailed planning required for a specific regional operations plan that will likely focus on shorter time horizons, like 3 to 10 years. The link between the long-range and more intermediate-range regional operations plan development could involve incorporating new performance measures.

During both the long-range and shorter term planning processes, TSMO scenario planning benefits from the inclusion of a wide range of public and stakeholder representatives. This could include land-use planners, transit agency representatives, bicycle and pedestrian interests, councils on aging, private technology developers and providers, system operators, freight and goods movement professionals, and other parties with a role or interest in transportation system design and performance. The purpose of including this broad constituency group is to ensure the cross pollination of ideas in identifying goals, developing scenarios, and discussing the tradeoffs of different paths for the future. It also benefits all parties to better understand the role TSMO strategies play in overall system performance and how they can continue to evolve in response to changing user preferences and data availability. Incorporating TSMO strategy considerations as part of larger transportation planning efforts also helps to build broad stakeholder awareness and understanding of TSMO needs and priorities, which in turn can help with early identification and support for TSMO funding.

Statewide Opportunities

At the statewide level, operations stakeholders typically led by the State DOT conduct planning activities and make multiple planning and investment decisions related to TSMO that can benefit from scenario planning. Just as regions develop plans for managing and operating the transportation system at a regional scale, States develop operations plans to address operations across the State. The statewide operations plans may be higher level documents that establish policies, goals, and operations objectives that provide guidance to their districts or metropolitan regions as they develop more detailed plans for operations. The statewide operations plans may also include plans for investments in TSMO projects that have statewide significance. State DOTs also incorporate planning for investments in TSMO in their overall transportation system investment planning process. This is illustrated in the text box below, which describes Minnesota DOT's scenario-based development of its 20-year State Highway Investment Plan.

Investing in Minnesota's Highways

The Minnesota Department of Transportation (MnDOT) conducted scenario planning during the process developing the 20-year State Highway Investment Plan (MnSHIP), which provides “a fiscally constrained investment direction” for the State.²⁸ The scenario planning process was based on ten investment categories:

1. Existing Roads.
2. Existing Bridges.
3. Roadside Infrastructure.
4. Safety.
5. Interregional Corridor Mobility.
6. Twin Cities Mobility.
7. Bicycle Infrastructure.
8. Accessible Pedestrian Infrastructure.
9. Regional + Community Improvement Priorities.
10. Project Support.

For the first nine investment categories, MnDOT defined four to five levels of funding, called performance levels, with the lowest level representing the lowest cost, greatest risk, and the highest level representing the greatest cost, lowest risk. Project Support is a fixed percentage allocated to delivering projects. It then developed three investment approaches representing different performance levels assigned across the investment categories:²⁹

Approach A – Focus on maintaining existing infrastructure (roads, bridges, roadside infrastructure).

Approach B – Maintain the current investment direction.

Approach C – Focus on meeting infrastructure needs on interstates and increasing investment in mobility, local priorities, and non-motorized transportation options.

MnDOT did not intend to adopt one investment approach “as is,” but rather to combine pieces of all three approaches. To present the approaches to the public through workshops and other outreach activities, MnDOT developed a web-based scenario exercise using the Citizing online tool.³⁰ The agency also developed “folios” that included: highlights of each approach; biggest strengths and drawbacks of each approach; and impacts of each approach (i.e., what could be accomplished with the money allocated to each investment category). In addition, the folios included a description of what each approach would look like 20 years in the future from the traveler’s perspective when making the “seven-hour drive from Winona to Bemidji...through

²⁸ Minnesota Department of Transportation, “MnSHIP Investment Approaches” (n.d.). Available at: <http://www.dot.state.mn.us/planning/mnship/pdf/approaches.pdf>.

²⁹ Ibid.

³⁰ J. Smith, “Participation by Design: Participatory Scenario Planning to Develop a 50-Year Transportation Vision,” PlaceMatters Blog. March 2012.

Investing in Minnesota's Highways (Continued)

Rochester, the Twin Cities and Saint Cloud before heading north.” For example, for Approach C, the description notes “You immediately notice that, while the interstates are in good condition, other roads are not,” and “Although traffic is slow through the heart of the metro, new lanes and some additional interchanges on I-94 and TH 10 allow for smooth traffic flow heading into and leaving St. Cloud.”³¹

As a result of the scenario planning process, MnDOT developed a 20-year investment plan included in MnSHIP.

Each of these statewide operations planning efforts seeks to answer questions that may be most effectively answered through a scenario planning approach. The following are types of questions that scenario planning can address in these TSMO planning efforts:

- What is the desired vision for statewide highway operations given several opposing priorities?
- What statewide investments for operations are needed to sustain a safe, efficient highway system with a significant increase projected for truck traffic (or other known trend that may impact the transportation systems operational performance)?
- What policies and TSMO investment areas should be targeted given uncertainty in climate change impacts (or future transportation technologies, budgets, etc.)?

There are several other TSMO-focused planning activities that occur at the State level. A few examples that could benefit from scenario planning are given below.

Transportation Management Center (TMC) Planning

Plans for the short-, mid-, and long-term management and operation of a TMC require planners to assess future staffing needs and make decisions about technology use and deployment as well as the level of service that can be provided to the public given funding constraints. Scenario planning can be particularly effective in addressing technology investment decisions given the uncertainty in new technology developments, costs, impacts on staffing needs, and whether the new technology will work with current technology. There is also uncertainty in projecting the demand for TMC services given the potential strains on the system by an increase in extreme weather events and the role of the TMC as vehicle automation becomes prevalent. By using exploratory scenario planning, TMC managers and stakeholders can examine alternative futures and determine how best to prepare the TMC for those potential realities. In addition, managers and stakeholders can look at different portfolios of TSMO strategies, staffing levels, and technology and examine the impacts of each portfolio against the desired performance expectations for the TMC and the transportation system.

³¹ Minnesota Department of Transportation, “MnSHIP Investment Approaches” (n.d.). Available at: <http://www.dot.state.mn.us/planning/mnship/pdf/approaches.pdf>.

Developing Work Zone Management Plans

A transportation management plan (TMP) for a work zone contains the work zone management strategies—such as travel demand management, signal retiming, and traffic incident management—that will be used for the project. For significant projects, the strategies must include both public information and transportation operations components to address the impacts around the work zone. TMP developers can use the trend-based type of scenario planning to discuss with stakeholders the impacts of a few different approaches to managing a major upcoming work zone and develop a preferred scenario based on thorough stakeholder input and analysis of impacts.

Developing a Statewide Freight Mobility Plan

Many States now have freight mobility plans to sustain and improve connections among markets within the State and connections from the State to national and international markets. These plans typically define policies and investments to improve intermodal freight mobility to increase the trade-related jobs and income for the State’s workers and businesses.^{32,33} Freight planning is a significant opportunity for the use of scenario planning because of the large number of uncontrollable and often uncertain driving factors that influence the success or failure of decisions regarding freight investment. In addition, freight involves a large number of stakeholders that need to be engaged in the planning effort and support the outcome. Through scenario planning, multiple perspectives can be brought to the forefront for analysis and discussion.

Corridor Opportunities

A corridor is a linear system of multimodal facilities and adjacent development. Corridors range in length from a few miles in an urban location to hundreds of miles for state or multi-state corridors. Given the diversity of corridors, scenario planning at that level can take many forms.

Similar to the regional approach, it will likely be driven by either a normative or predictive approach and may go through multiple iterations. In the normative approach, corridor scenario planning is best applied as a method for creating consensus on the overall vision or function of a corridor. This type of exercise typically emerges from tensions between transportation mobility and accessibility objectives in response to changing development patterns. In many urbanized areas, arterial corridors are increasingly being looked at for redevelopment and infill opportunities to support local economic development or growth management goals. With intensifying patterns of mixed use development comes a new emphasis on or a desire to increase transportation choices (mode split to transit, biking and walking).

Scenario planning in this context may involve the development of two or three big picture alternative visions for the corridor driven by differing redevelopment assumptions and includes a range of transportation targets for mode split, travel time by mode, pedestrian access to

³² Freight Advisory Committee, “Texas Freight Mobility Plan” Web page. Available at: http://www.dot.state.tx.us/move-texas-freight/freight_plan.htm.

³³ Oregon Department of Transportation, “Transportation Development Planning – Oregon Freight Plan” Web page. <http://www.oregon.gov/ODOT/TD/TP/pages/ofp.aspx>.

destinations, person throughput in corridor, auto travel time to the central business district, etc. For each scenario, TSMO professionals will be critical to identifying appropriate corridor-based TSMO strategies to achieve the desired targets. This process could also reveal new data collection and data collection technology needs that can be incorporated into subsequent TSMO planning efforts.

Opportunities to Consider Implications of Emerging Trends

Scenario planning is an excellent tool for considering TSMO issues and opportunities associated with “game-changing” demographic, economic, environmental, and technological trends. The section below highlights TSMO-related issues associated with emerging vehicle technologies and with generational demographic shifts which could be incorporated into scenario planning initiatives.

Connected/Autonomous Vehicle Technologies

The American Association of State Highway and Transportation Officials (AASHTO) Connected Vehicle Field Infrastructure Footprint Analysis asserts most motorists on American roadways by 2040 will be traveling in connected or automated vehicles (C/AV).³⁴ The preponderance of these technologies have a variety of potential outcomes that could be considered in long-range scenario planning exercises. Highway crashes will be dramatically reduced when vehicles can sense and adjust to surrounding events and hazards. In addition to the social and economic benefits of improved safety, reduced crash rates will also help to lessen incident-related congestion and thus improve travel-time reliability. Environmental impacts of vehicles and travel can be reduced when travelers can make informed decisions about modes and routes and when vehicles can communicate with the infrastructure to enhance fuel efficiency by avoiding unnecessary stops. Drivers can be provided with information about the proper speed to optimize their green light times on arterial corridors, and vehicles can be diverted to alternative routes in response to real-time congestion. C/AV vehicles can also be lighter than standard vehicles without compromising safety; the correspondingly improved fuel efficiency would have implications for both energy and environmental analyses.

Planning-related C/AV scenarios could also address land use, development strategies, and economic activity. With increased automation, car sharing may evolve into a service-on-demand industry that would shift car ownership from individuals to fleets. This would allow greater urban densities since parking requirements could be relaxed. Automated vehicles could replace existing inefficient transit feeder services and some line-haul services as well. On the other hand, these developments may result in reduced land-use density, since commuting time can be used more productively.

In addition to planning for the long-term benefits of fully deployed C/AV technologies, TSMO planners can incorporate shorter term impacts of gradual system deployment. Initially there may be C/AV-only highways or lanes, with some level of automation or platooning provided.

³⁴ American Association of State Highway and Transportation Officials with the FHWA and Intelligent Transportation Systems Joint Program Office, *National Connected Vehicle Field Infrastructure Footprint Analysis Final Report*, FHWA-JPO-14-125 (Washington, DC: 2014). Available at: http://ntl.bts.gov/lib/52000/52600/52602/FHWA-JPO-14-125_v2.pdf.

In the medium term C/AV could support integrated corridor management (ICM) strategies by automatically balancing traffic between freeways and arterials. Small groups of drivers could be diverted with targeted messages, for example, which would be more effective than general dynamic message signs. It is important to note that the C/AV market may evolve gradually over decades, resulting in a mix of traditional and C/AV vehicles on roadways for years to come. Many other roadway users will not be in motor vehicles at all, such as pedestrians and bicyclists. Scenario planning processes provide opportunities to construct an understanding of these issues and implications and to develop new performance measures to track the emerging implications of new technologies.

Demographic Trends

Shifting cultural norms and generational needs and preferences have the potential to significantly affect travel demand in decades to come. America's up-and-coming workforce, dubbed the "Millennial" generation, is demonstrating significantly less interest in car ownership and a stronger preference for housing and employment in walkable, mixed-use towns and cities than their generational predecessors. It is not yet clear whether these preferences will "stick" as this generation moves into its child-raising years, but market studies indicate there is reason to believe that this generation will play an important part in generating demand for urban development and increased transportation choices that include more transit, walking, and biking options to meet their daily transportation needs.

Similarly, the aging "Baby Boomer" generation whose "nests" are emptying of young adult children is also demonstrating an increasing interest in walkable communities and urban lifestyles as they downsize their homes and anticipate the possibility of eventually choosing (or being forced) to give up driving. Scenario planning forecasts for medium- and long-term TSMO planning initiatives for corridors, regions, and States can be adjusted to consider related potential increases in urban density, mixed-use activity centers, and multimodal travel markets.

Environmental Trends – Weather Patterns

Scenario planning can also be an effective tool to help set specific performance targets for the transportation system under extreme weather conditions, which have been occurring with more severity and frequency over the past several years. After a significant event, like a major snow or ice storm in a southern city that shuts down the major highway system, policy makers and the public often express frustration over extreme commute times, stranded vehicles, and associated economic losses. Yet quite often the community or the region may have never asked themselves the question, "What is reasonable given certain extreme conditions?" While it may be difficult to anticipate or plan for a wide range of extreme events, a scenario planning process might be effective in helping to set expectations (as defined by performance measures) and reprioritize capital investments and management and operations plans.

To do this, a State or a region could develop a set of scenarios differentiated by different performance objectives in response to a major weather event. This would involve engaging a wide stakeholder group including first responders, major employers, schools, emergency workers,

elected officials, and others to first begin a dialogue to establish priorities relative to making the transportation system operational after a major event. This group can then help to drive the scenario development. In the case of an extreme snow event, for example, performance targets could include making all roads accessible within 4 hours of the incident, making primary roads accessible to emergency crews only within 4 hours, or ensuring that all roads are cleared within 12 hours of the event. The scenarios could also look at economic impacts and focus in more strategic locations where interstate commerce or access to and from the regional central business district (CBD) may be a priority. Each scenario would be developed to include the full range of investments, new communication protocols, and other strategies needed to achieve the desired performance targets.

These scenarios could then be evaluated with the stakeholder group to discuss the tradeoffs—and most likely the benefit-cost analysis associated with the different levels of performance. This dialogue would likely result in a consensus on a set of performance objectives that can be achieved in response to an extreme event given specific funding levels or investments. This process could also likely lead to enhanced coordination and communication with the general public about how to better prepare and what to expect should a future event of extreme nature happen in their community.

Section 5: Illustrations of Scenario Planning for Transportation Systems Management and Operations

This section provides three hypothetical examples that illustrate how scenario planning approaches can be used to advance transportation systems management and operations (TSMO) concepts in the context of various planning efforts. For each phase, the questions driving the phase's planning activity and example outputs are provided. The three fictional examples are:

- **Southcom Coalition: Planning for Operational Resilience During Tropical Storms** – A regional transportation operators coalition uses scenario planning to identify strategies for improving system resiliency in the face of increasingly intense and frequent storms.
- **Corridor Q: Development of a Multimodal Corridor Operations Plan** – A State department of transportation (DOT) and a metropolitan planning organization (MPO) partner with TSMO agencies to conduct a scenario planning process aimed at building consensus on strategies to balance local accessibility and regional throughput on a busy suburban arterial.
- **Fairview Metro Plan: Development of Regional TSMO Strategies** – Facing challenges of declining funds and rising congestion, a metropolitan region uses scenario planning to identify strategic TSMO investments that optimize roadway capacity at the least possible cost.

Each hypothetical project description includes a brief summary of the context, a set of questions considered during each of the six scenario planning stages, and the outcome of the process.

Southcom Coalition: Planning for Operational Resilience during Tropical Storms

Southcom is a regional transportation operations coalition of traffic, transit, and public safety agencies in 16 jurisdictions across three States. It operates on a 24/7 basis to tie together the agencies for regional traffic incident management (TIM), implementing intelligent transportation systems (ITS), and emergency management. In the past 2 years, the Southcom area has had more frequent and stronger tropical storms that have flooded primary roads and subway systems, caused widespread power outages, and damaged bridges and other infrastructure. Southcom leaders have decided to use scenario planning to improve transportation system resiliency during major storms over the next 10–15 years. Their goal is to identify the investments and actions needed to prepare for future storms.

Phase 1: Getting Started

Questions to address: What do we want to accomplish? What are the important issues or uncertainties to consider? Who should be involved? What type of scenario planning do we need?

- Southcom leaders and staff from member agencies determined that they wanted to identify the operational strategies—including new ITS and communications infrastructure—that would be needed to prepare for future storms.
- Southcom member agencies identified the primary area of uncertainty as being the timing, number, strength, and duration of storms. They anticipated that Southcom systems would continue to be stressed, and so climatological data and forecasts for the region would need to be considered.
- This scenario planning effort was led by the Southcom leadership committee along with the operations, planning, and emergency management staff from coalition’s agencies, including the cities, counties, port authorities, transit operators, State DOTs, Federal Emergency Management Agency (FEMA), and others. Southcom decided to involve a variety of additional stakeholders, including local businesses, commuters, and other members of the public.
- Southcom scenario planning participants used the exploratory type of scenario planning because they were looking to examine the potential impacts of several storm scenarios and identify the best response based on this uncertainty.

Phase 2. Where Are We Now?

Questions to address: What does the recent climatological data for this region say about size, frequency, and timing of past tropical storms? What are the climatological forecasts for this region over the next 10–15 years and how certain are the forecasts? What has been the impact on transportation system operational performance during recent major storms? What are the strengths and weaknesses of our coordination of emergency transportation operations during these storms?

- Climatological data show that annual precipitation has varied over time, showing a clear shift towards greater variability and higher totals since 1970. There are recent elevated levels in extreme precipitation and shorter rainfall recurrence intervals. The amount of rain that constituted a 50-year event during 1950-1979 is expected to occur on average once every 30 years based on the more recent data.
- The region has experienced 18 tropical storms, including two hurricanes in the last 5 years with significant impacts on travel and goods movement.
- The strengths of Southcom’s emergency operations during storms included participation by all necessary agencies on hourly calls and consistent messages provided to the public. Weaknesses included a traveler information website outage during most recent storm and difficulty publicizing travel conditions information (with the exception of freeways in the metro areas) in a timely manner.

Phase 3. Where Do We Want to Go?

Questions to address: What are the values and priorities that are relevant in selecting TSMO strategies? What are the goals and operations objectives for transportation system operations during tropical and other major summer storms? How will we measure progress?

- Southcom's goal: Provide a resilient transportation system that enables the safe and reliable movement of people and goods and supports the region's economic well-being.
- Southcom's operations objectives (performance measures underlined):
 - Within 10 years, 50 percent reduction in loss of life, property, and injury on roadways or rails during tropical storms.
 - Average travel times on the freeways, primary arterials, and rail without structural damage is back to normal within 24 hours of a level one storm and within 48 hours of a level two storm

Phase 4. What Could the Future Look Like?

Questions to address: Given the current trends and operations objectives, what are the scenarios we should consider in exploring the preferred approach to system resiliency? What are the TSMO strategies needed to realize these scenarios?

- **Triple Hit Scenario:** The Southcom area is hit by three hurricanes (Category 2 or less) during one tropical storm season, each within just a couple weeks of another. The largest metropolitan area in the Southcom region is directly under the eye of one of the storms with road flooding and signs and traffic signals damaged.
- **Business as Usual Scenario:** The Southcom area receives roughly the same number, intensity, and frequency of hurricanes and other tropical storms as it has over the past 5 years.
- **The Big One Scenario:** A Category 5 hurricane hits the Southcom area and major roads are cut off. Rail systems are unable to function and many buildings are destroyed.

Southcom determined that the most effective TSMO strategies across the scenarios would be highly redundant data and voice communications systems, several backup servers and databases located over 750 miles away, backup power for all variable message signs and traffic signals, inclusion of additional stakeholder groups into coalition, additional closed-circuit televisions (CCTV) on roads and rails, and road weather information systems (RWIS) in rural areas.

Phase 5. What Impacts Will the Scenarios Have?

Questions to Address: What are the impacts of these scenarios on the region's transportation system? What are the benefits and costs of the TSMO strategies selected to handle each scenario? How well do the strategies help achieve Southcom's objectives in each scenario? What level of system resilience is desired or obtainable within the current resource constraints?

Using a combination of analysis tools, models, and expert opinion, the group assessed the expected impacts of the three scenarios and selected TSMO strategies on loss of life, property, and injury on roadways or rails and the recovery time of the system.

Phase 6. How Will We Achieve Our Desired Future?

Questions to address: Based on the three scenarios, how do we best create resiliency in our transportation system operations? What have we learned about the effectiveness of TSMO strategies? What projects or programs should be developed to support the preferred way forward?

The stakeholders found benefits in the TSMO strategies used to respond to each of the scenarios and merged together the elements of each scenario to develop a preferred set of solutions that incorporated communications system redundancy, increased monitoring, and extended the hardening of traffic control devices.

Outcome: Plan for Operational Resiliency during Tropical Storms

The direct result of this scenario planning activity was the development of a strategic plan for creating greater operational resiliency, including operations objectives, performance measures, and a list of operational investments and actions to improve Southcom's coordination during emergencies.

Corridor Q: Development of a Multimodal Corridor Operations Plan

Corridor Q is a six-lane arterial that parallels a major highway (just two miles away) and is dominated by older shopping centers, fast food restaurants, and some older two-story office buildings. It serves as one of the main corridors connecting several residential neighborhoods to shopping destinations, and also provides a link into the traditional downtown commercial business district and the region's major job center about 10 miles away. The regional economy is strong, and there are mounting pressures to redevelop and infill along this corridor at higher densities. Local businesses and residents may welcome this new development, but have concerns about how best to address the additional travel caused by the development. There is also a strong sentiment among local residents that it would be counterproductive to take land to accommodate additional lanes of roadway, and there is interest in both increasing transit service along the corridor and making the areas on each side of the arterial more walkable. The State DOT, in coordination with the MPO, has decided to lead a scenario planning effort to look at different visions for how the corridor might evolve over time and identify the TSMO goals, objectives, and strategies that can best support that vision.

Phase 1: Getting Started

Questions to address: What do we want to accomplish? What are the important issues or uncertainties to consider? Who should be involved? What type of scenario planning do we need?

- The desired outcome was to help participants reach consensus on a preferred vision for travel conditions in the corridor and develop the framework for the creation of a corridor operations plan.
- Additional outcomes may involve the identification of potential land-use and transportation policy changes in addition to specific transportation design and operational improvement projects.
- To develop the scenarios, participants needed to include land-use planners, economic development practitioners, transit agency partners, traffic operations staff, transportation planners, housing agency representatives, and other interested stakeholders in the process.
- Participants agreed to apply a normative type of scenario planning to examine different desirable future scenarios for the corridor and reach consensus on a vision.

Phase 2. Where Are We Now?

Questions to address: What are the existing conditions and the trend forecast? What are the forecasted operational conditions?

- Existing conditions were defined by current development patterns (density and mix of use) within a half mile, socio-demographics, tax revenues, auto and transit travel time, corridor travel time reliability, current non-auto mode splits, vehicle miles traveled (VMT) per capita, percent truck traffic, signal timing data, crash rates, air quality indicators, etc.
- The trend forecast included projecting out future travel demand (using the regional travel demand model) based on regional growth trends and existing policies over a 20-year horizon.
- Participants noted that while specific operational conditions might be difficult to forecast, a sketch-planning method to correlate reliability with levels of congestion might be beneficial as part of the trend analysis.
- Sample data provided the following overview of the corridor:
 - Daily traffic volume was 55,000, with peak hour volume of 4,950 and peak direction of 2,970.
 - Volumes were projected to increase to 60,000 vehicles per day; this increase is predominantly from regional through traffic.
 - There were eight intersections and one major cross street with similar volumes.
 - Bus stops were about 0.8 miles apart – there are no bus bays.

- The signal system was interconnected.
- The signal timing plans had not been updated in more than 5 years.
- Stretches along the corridor experienced access management challenges.

Phase 3. Where Do We Want to Go?

Questions to address: What are the community values and priorities that are relevant for this corridor’s future? What are the TSMO goals and objectives for the corridor? How will we measure progress?

- Some community constituents wanted to see the corridor maintained as a high-mobility corridor, providing high-speed access between the suburbs and downtown.
- Others saw the corridor evolving into more of a destination corridor driven by market demand for infill and redevelopment with significantly more jobs and housing.
- All constituents wanted to encourage redevelopment to improve the aesthetics, bring in new amenities, and contribute to the tax base—but they do not want that new growth to diminish accessibility for those living adjacent to the corridor.

Given these goals, the stakeholders identified some operations objectives and performance measures to gauge progress and evaluate scenarios. These included travel time for auto and transit, number of destinations within walking distance, levels of congestion, economic development, and cost.

Phase 4. What Could the Future Look Like?

Questions to address: In light of the current system data, trends, and community goals, what are the scenarios we should consider? What are the TSMO strategies needed to realize these scenarios

- New Destination Scenario would target a single, large redevelopment project at a major arterial intersection with a large new office and mixed use complex. Mobility through the corridor would still be a major goal, but the primary intersection along the corridor would now be a key job destination. TSMO strategies include: signal priority, grade-separated intersections, express buses to a new job center, high-occupancy vehicle (HOV)/carpool lanes, transportation demand management (TDM) strategies, system timing, and access management.
- Livable Corridor Scenario would focus on infill and redevelopment by adding new, higher density residential space and smaller scale neighborhood retail along the corridor. This new housing would be aimed at a younger, professional generation with a preference for more “car-lite” lifestyle. This new residential space would be dispersed along the corridor, and these new residents would still need to get to jobs in the downtown, but they will do so by using transit and accessing non-work destinations through more walking and biking options. TSMO strategies included signal priority for buses, dedicated bus lane and express buses, TDM for the central business district (CBD), limited parking at the CBD to reduce the amount of automobile traffic to the CBD, bike sharing in the CBD to facilitate pedestrian

movement at the CBD, and improved pedestrian signalization and crossings between adjacent parcels along the corridor.

- Get-Me-to-Town Scenario would assume that development patterns would not change all that much and the corridor would remain a through corridor for transit and autos. The goal of the third scenario was to improve auto and transit mobility to and from the central business district. TSMO strategies included: signal priority, grade separated intersections, dedicated busways, HOV/carpool lanes, TDM strategies, signal timing, and access management.

Phase 5. What Impacts Will the Scenarios Have?

Questions to address: Which set of development and transportation concepts perform best against community goals? How does each scenario perform against our measures? How does each scenario contribute to reaching our objectives?

- While the Get-Me-to-Town Scenario performed well with improved auto and transit travel times to the CBD, that scenario did not support the economic development objectives of the community and it reduced the viability of significant new development within the corridor.
- The Livable Corridor performed well in supporting economic development, but added additional congestion to the corridor, which in turn could negatively impact the economic viability of the CBD.
- The New Destination Scenario supported economic development, the investment and time required were a deterrent for many stakeholders.

Phase 6. How Will We Achieve Our Desired

Questions to address: What is our preferred scenario, or, is there a combination of scenarios that we would like to adopt? What projects or programs should be developed to support the preferred way forward?

- The group determined that none of the three scenarios seemed vastly superior and determined that the best course of action would be to combine concepts from all three into a hybrid approach.
- The hybrid approach included creating limited nodes of compact, mixed-use development distributed along the corridor. This would entail the following:
 - Walkable street grids and frontage streets that would be developed at each node and connected with the arterials at major intersections.
 - Improved signal timing along the arterial to ensure auto and transit speed improvements.
 - Limited transit stop locations to locations at key development nodes.
- The goals of this approach were to have comparable transit and automobile travel times and travel time reliability to the CBD and to increase transit mode share.

Outcome: Clear Vision for the Corridor and TSMO Strategies to Achieve that Vision

The scenario process allowed for a more robust discussion of the range of TSMO strategies that could be applied within the corridor. At the end, there was clarity in the need to align data gathering, monitoring, and signal timing to optimize both auto and transit travel to and from the CBD. There was also a need to improve pedestrian safety and signal timing at major intersections and transit stops.

Fairview Metro Plan: Development of Regional TSMO Strategies

The Fairview Regional TSMO Committee, hosted by the Fairview MPO, sought to exert a stronger operations influence on the next update of the metropolitan transportation plan (MTP). Over the coming 20 years, the region expects to experience major cuts in transportation funding and a projected tripling of peak period congestion on area freeways and primary arterials. Local leaders are increasingly looking at the potential for low-cost operational improvements as an alternative to high-cost capacity expansion projects to reduce congestion and improve accessibility. The committee worked to develop a Fairview Regional TSMO Plan to identify TSMO investments for consideration in the pending update of the MTP, and in programming decisions by individual member agencies. They had already developed the TSMO plan goals, operations objectives, and related performance measures. The committee then decided to use scenario planning to select the most cost-effective TSMO strategies to recommend for the MTP.

Phase 1: Getting Started

Questions to address: What do we want to accomplish? What are the important issues or uncertainties to consider? Who should be involved? What type of scenario planning do we need?

- The Fairview Regional TSMO Committee wanted to identify the most cost-effective set of TSMO strategies to reach its objectives.
- The committee decided that it needed to consider the trend of significantly increasing delay with almost no system expansion possible.
- The effort was led by the TSMO Plan Steering Committee of the MPO with support from operations and planning staff from agencies in the region including the city, county, port, transit, State DOT, and others. The committee involved a variety of stakeholders, including public safety, towing, local businesses, commuters, and other members of the public.
- The scenario planning participants used the predictive type of scenario planning because they were looking for transportation packages that would be most effective in light of the likely trends.

Phase 2. Where Are We Now?

Questions to address: What are the current travel and goods movement measures that will help us identify the largest sources of delay and unreliability? Where, when, and why is our greatest congestion occurring? What are the growth, travel demand, and mode share trends that will help us identify effective strategies? What are the most significant challenges for our system managers and operators?

- The MPO's most recent travel demand forecasting model outputs identified the greatest growth in demand coming from the northwest quadrant of the region toward the center in the morning and back out in the evening. Freight truck travel will increase by 20 percent over next 10 years, and the region will experience an increase in walking and biking by 25 percent in 10 years. Transit and car-sharing will increase by 10 percent in 10 years.
- Areas of freeways and primary arterials with greatest delay during peak periods were confirmed with archived speed data, and when matched with incident and work zone area data, these two types of events were found to be the primary contributors to unreliable travel.
- Traffic management center operators, local traffic engineers, and bus operators provided qualitative information that helped identify several other key factors.

Phase 3. Where Do We Want to Go?

Questions to address: What are the community values and priorities that are relevant in selecting TSMO strategies? What are the goals and objectives for the TSMO Plan? How will we measure progress?

- The TSMO plan goal was to provide a safe, efficient, and reliable multimodal transportation system.
- The following were the TSMO plan operations objectives (performance measures underlined):
 - Hold average travel time during peak periods at 2015 levels during the next 10 years across all modes.
 - Improve the planning time index, a measure of travel time reliability, by 20 percent by 2020 on freeways and primary arterials.
- Top community values include economic growth, jobs, and clean air.

Phase 4. What Could the Future Look Like?

Questions to address: In light of the current system data, trends, and top community values, what are the scenarios we should consider in identifying the preferred approach to meeting our operations objectives? What are the M&O strategies needed to realize these scenarios?

- All-Knowing Traveler Scenario: Investments would focus on regional traveler information including transit, parking, and commercial vehicle operators. Real-time and predictive information would be ubiquitous and travelers would adjust their own route, mode, and time of travel based on this information.
- Do-Not-Disturb Scenario: Investments would focus on reducing disruptions to travel quickly and safely. This would include improved transportation management center (TMC) capabilities, TIM, work zone management, special event management, and road weather management.
- Manage-Me Scenario: The focus here would be on managing traffic flow and travelers to maximize the effective capacity of the system. This would include variable speed limits, flexible lane use, ramp metering, enhanced traffic signal operations, geometric improvements at intersections, transit signal priority, truck electronic screening or clearance programs, and access management.

Phase 5. What Impacts Will the Scenarios Have?

Questions to address: What are the benefits and costs of each scenario? How does each scenario contribute to reaching our objectives?

Using a combination of analysis tools, models, and expert opinion, the group assessed the expected impacts of the three scenarios on hours of delay, planning time index, and air quality. They also discussed how each scenario would contribute to the regional economy and job growth.

Phase 6. How Will We Achieve Our Desired Future?

Questions to address: What is our preferred scenario, or, is there a combination of scenarios that we would like to adopt? What projects or programs should be developed to support the preferred way forward?

The stakeholders found benefits in each of the scenarios and merged together the lower cost elements of each scenario to develop a preferred set of solutions that incorporated traveler information and choice, minimizing disruptions, and managing traffic flow.

Outcome: Package of TSMO Strategies for the Regional TSMO Plan

The direct result of this scenario planning activity was the identification of a package of TSMO strategies that were cost-effective, helped to bring the region closer to its operations objectives, and took into consideration the top values of the community.

Section 6: Getting Started

Through the six-step approach described in Section 3, transportation systems management and operations (TSMO) staff at metropolitan planning organizations (MPO) and departments of transportation (DOT) can organize a thoughtful, collaborative process for engaging partner agencies, organizations, private sector interests, stakeholders, and the general public in considering TSMO-related issues and opportunities. Below are a few key questions to consider when “mapping out” a scenario planning effort for TSMO.

1. How should we get started?

- What do we want to accomplish/address?
- What is the geographic area and timeframe?
- What are the pressing issues or desired areas of change?
- Who should be involved in the process? Why? How will their involvement influence the planning process and implementation?
- Consider convening a series of scenario planning workshops for TSMO to gather stakeholder input during the subsequent phases.

2. Where are we now?

- What data will be needed to address our questions? Data could include, for example, travel time reliability; delay, congestion, safety-related, or incident management statistics; transit ridership trends; etc.
- What information is needed to provide context for the planning process? What are the policies or conditions that could influence, or be influenced by, the outcomes of the process? Contextual information could include factors that affect travel demand (such as current and planned land uses), and environmental conditions such as historic weather patterns.

3. Where do we want to go?

- What are the goals, objectives, targets, and/or desired future conditions to be addressed? Will these be established or updated as a result of the process?
- For context, consider current community-based goals, policies, and statements of desired conditions, such as goals from local, MPO, and State DOT plans, local land-use plans, complete street policies, sustainability initiatives, etc.
- Consider contingent or conditional factors that could negatively impact the ability to achieve the goals or desired conditions.

4. What could the future look like?

- What types of scenarios will be developed? Which variables will remain constant, and which will change? Below are some examples:
 - Predictive: Different packages of transportation strategies for the study area, each of which is designed to achieve the same desired end state.
 - Normative: Different end states for the study area, influenced by packages of transportation investments and land-use policies organized around policy-driven themes.
 - Exploratory: Different end states for the study area, influenced by major changes in outside forces such as global economic shifts, weather events, or environmental conditions.

5. What impacts will scenarios have?

- What are the key factors that will be tested during the process? For example –
 - Predictive: Impacts of different transportation investment packages on budgets and/or system performance goals.
 - Normative: Effects of different combinations of transportation investments and land-use, economic, and environmental management policies on desired future conditions as defined by community values.
 - Exploratory: Influence of different outside forces on system performance and related outcomes or conditions.
- What analysis tools will be used to test these impacts and evaluate the results with stakeholders?

6. How will we reach our desired future?

- What will the end product of the process be? How will the scenario planning process inform that end product?
- How will stakeholders engage in the process of defining goals, crafting scenarios, and evaluating results?
- Who will be involved in implementing the end product of the scenario planning process? How might their everyday business plans be affected by the results?

Scenario analysis methods are useful tools for examining the increasingly complex interplay of issues, technologies, and stakeholders involved in developing plans and making decisions regarding TSMO. This also holds when TSMO strategies are considered within the context of a broader planning initiative. Over the past decade, the level of interest in TSMO among transportation officials and public decisionmakers has risen due to an increased emphasis on developing cost-effective, performance-driven transportation solutions that optimize increasingly sophisticated technologies. State DOTs and MPOs that traditionally focused planning efforts on long-range capital investments are now elevating TSMO to a top priority in order to increase

operational capabilities of existing systems. MPOs are spearheading regional collaboration for TSMO by bringing together stakeholders from State, regional, and local public and private transportation agencies and interests. Local governments, which are typically responsible for operating traffic signals, transit services, road maintenance, snow removal, local policing, and other services, are increasingly involved in regional efforts as TSMO strategies become part of corridor, local, and subarea plans. The private sector is also playing a major role in influencing traveler behavior and system operations by providing real-time traveler data to handheld devices. By engaging multiple agencies, jurisdictions, stakeholders, and the private sector, scenario planning can function as a useful framework for bringing together a wide variety of stakeholders to consider a complex array of inter-related issues and concerns, and to identify ways in which they might work together to leverage resources toward mutually beneficial solutions.

The results of planning for TSMO influence activities such as signal coordination, incident management, congestion pricing, and ridesharing programs; technology infrastructure; data gathering needs; and others. Advances in vehicle and infrastructure technology and communication systems are introducing new paradigms for improving travel safety and efficiency by coordinating interactions among infrastructure, vehicles, operators, and human behaviors. The continuing evolution of public policies in response to changing community goals and traveler behavior is creating the need to identify new measures of effectiveness for TSMO. Scenario planning methods can help agencies responsible for TSMO to explore the potential opportunities and impacts associated with new and emerging technologies before they are deployed. Scenario planning can also help an operating agency and its partners to optimize their strategy for maintaining safe, efficient travel in an area where some changes are likely but not yet fully defined. In addition, scenarios can help demonstrate the specific TSMO strategies necessary to support community goals relative to creating more effective multimodal transportation systems.

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