Note: This report contains material relevant to NCHRP Project 20-83(03)A extracted from:

Phase I Interim Report

to the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM (NCHRP)

on Project NCHRP 20-83(03) Long-Range Strategic Issues Affecting Preservation, Maintenance, and Renewal of Highway Infrastructure

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EXECUTIVE SUMMARY

INTRODUCTION

The transportation industry continually faces new challenges that influence transportation needs and priorities, particularly in the preservation, maintenance, and renewal of the highway infrastructure.

These challenges result from long-range changes in many *technical areas*, such as:

1. Technology and innovations (e.g., high-performance materials, construction equipment and methods, and information and monitoring systems).
2. The environment (e.g., climate change and sustainability).
3. System performance (e.g., accelerated deterioration and accountability).
4. Security.
5. Natural-resource availability (e.g., fuel and construction-material availability).
6. Finance and budget (e.g., global economics, contracting methods, revenue sufficiency, and costs).
7. Human resources (e.g., skills, education, and training).
8. Coordination (e.g., among transportation modes and related industries).
9. Regulations and policies (e.g., environmental regulation and the changing role of governmental identities).
10. Demographics (e.g., population characteristics and land use, including urban/rural differences).
11. Customer needs and expectations.
12. Traffic (e.g., speed, loading, density, and volume).
13. Safety (e.g., work zones and construction).

Research is critical to address the challenges in these technical areas. Transportation stakeholders must be able to:

- Anticipate future issues.
- Explore the potential role of new materials, tools, approaches, and technologies in developing and preserving highway infrastructure.
- Develop guidance on how such materials, tools, approaches, and technologies can enhance system preservation, maintenance, and renewal in response to anticipated challenges.

RESEARCH OBJECTIVE AND SCOPE

The objective of this research is to develop guidance for transportation stakeholders for using emerging materials, tools, approaches, and technologies. This guidance will allow stakeholders to deal with long-range (30 to 50 years in the future) highway infrastructure maintenance, preservation, and renewal needs and ensure satisfactory system condition and performance.

The 20-83 (03) research project has four phases. This report covers the first phase. Phase I has:

- Identified future factors and trends that could significantly influence infrastructure maintenance, preservation, and renewal.
- Assessed the likelihood and impact of various scenarios on future needs.

SCENARIO PLANNING METHODOLOGY

The research methodology used to conduct the Phase I research was scenario planning. The scenario planning methodology is a strategic planning method that organizations use to make flexible long-term plans. It recognizes that many variables may combine in complex ways to create unexpected futures. By building expected and alternative futures, organizations can evaluate possible scenarios in advance and then devise measures to minimize the negative impacts and build on opportunities.

The following questions can be addressed through the scenario planning methodology:

- What are the key influential factors (drivers) of the system?
- How can the system thrive under various possible future conditions?
- What are the early signals indicating the likelihood of dominance for certain scenarios?
- What are the strategies to mitigate possible risks associated with dominating scenarios?

Scenario planning guided the assessment of future impacts in the 13 technical areas using six "worlds" from another 20-83 study, 20-83 (07), *Sustainable Transportation Systems and Sustainability as an Organizing Principle*. A world in this context is an environment shaped to build a comprehensive picture of a possible future and to develop a broad list of uncertainties that exist in each technical area. The worlds reflect alternative futures that range from highly negative to highly positive.

Researchers used information from publications, Internet sources, and research team expertise to identify drivers in each of the 13 technical areas that influence the six worlds. Drivers in this context are forces that influence the future, such as climate change or economic growth. The research team identified 67 unique drivers and developed 78 different worlds (six worlds for each of the 13 technical areas).

The technical-area drivers and worlds are a knowledge base of information that researchers used to develop 21 specific key drivers expected to influence future transportation needs. This output was derived initially from a one-day workshop facilitated by the research team's futurist. These 21 drivers covered the majority of the original 67 technical-area drivers.

The research team described the 21 drivers in terms of an expected "baseline" future based on trends (direction of change) and rates of change. They also described possible alternative futures. The 21 drivers were analyzed using statistical tools to determine which drivers were most related to each other. Three drivers were combined as a result of the statistical analysis, so the final number of drivers was 18. The research team used this analysis and the expected baseline and alternative-future descriptions to create groups of common drivers, which became the basis for creating six multi-driver scenarios.

SIX MULTI-DRIVER SCENARIOS

Six multi-driver scenarios were developed based on an extensive statistical analysis of the 18 drivers and their relationship to each other, as well as the expected baseline and alternative futures. The six multi-driver scenarios are:

- **Back to the Future:** The economy returns to health, and transportation has the technology and resources to grow again.
- **Government Redux:** The government reasserts itself as the primary driver of transportation in the United States and develops the funding resources to do so.
- **Bits over Buses:** A higher than expected increase in crude oil reduces the ability of ordinary people to travel as much as they used to. They turn instead to an expanded Internet, not only for communication but for most work and leisure activities that used to require physical movement.
- **Many Ways to Go:** The government seeks new revenue in gas and carbon taxes, but rather than investing in the existing transportation system, it puts its money into new transport and information technology. This leads to a complex but efficient transportation system that includes significant shares of many different modes.
- **Escape to the Center:** The lack of mobility and increased threats to their well-being drive people out of the suburbs and into the city, reducing the demand for transportation—the arrival of the vision for the advocates of smart growth.
- **Meltdown:** The pessimistic scenarios for climate change ends up being more accurate than the optimistic ones. As a result, the most important priority for the next few decades is struggling with nature rather than growing the economy.

KEY FINDINGS

The key findings are:

- The six worlds created for each of the 13 technical areas helped develop the research team's understanding of the future state of each technical area.
- The 21 key drivers represent most of the drivers mentioned in the technical-area descriptions.
- The 21 drivers were reduced to 18 drivers when developing the multi-driver scenarios. The final 18 drivers are:

    - Climate change.
    - Economic growth.
    - Priority on environmental quality/public commitment to sustainability.
    - Funding—amount.
    - Funding—proportion private.
    - Government role.
    - Mobility—demand.
    - Mobility—capacity and access.
    - Population density.
    - Resources/energy—supply.
    - Resources/energy—demand.
    - Resources/energy—gas or carbon tax.

  - Resources/energy—price.
  - Road freight.
  - Security.
  - Technology—physical and fixed.
  - Technology—information technology.
  - Transportation choices/complexity.

- The six multi-driver scenarios are based on an extensive statistical analysis of the drivers and their relationship to each other, as well as the expected baseline and alternative futures.
- Scenarios can reflect a negative future, a positive future, or a future somewhere in between. This variability will influence the extent of development of new materials, tools, approaches, and technologies to meet future needs for maintaining, preserving, and renewing the highway infrastructure.

PHASE II AND BEYOND

The work accomplished in Phase I and described in this report establishes a sound basis for Phase II: Vision Development. Phase II will develop visions and comprehensive strategies for a future sustainable highway infrastructure based on the identified materials, tools, approaches, and technologies. Barriers will also be identified. An updated work plan for Phase II is provided in the last chapter of this report.

Phase III: Guidance and Communication will build on Phase I and II work to develop guidance documents and communication packages. In Phase IV: Deliverables, the research team will prepare and submit project deliverables, including a final report.

CHAPTER 1: INTRODUCTION

RESEARCH PROBLEM

The transportation industry continually faces new challenges that influence transportation needs and priorities, particularly in the preservation, maintenance, and renewal of the highway infrastructure.

These challenges result from long-range changes in many *technical areas*, such as:

1. Technology and innovations (e.g., high-performance materials, construction equipment and methods, and information and monitoring systems).
2. The environment (e.g., climate change and sustainability).
3. System performance (e.g., accelerated deterioration and accountability).
4. Security.
5. Natural-resource availability (e.g., fuel and construction-material availability).
6. Finance and budget (e.g., global economics, contracting methods, revenue sufficiency, and costs).
7. Human resources (e.g., skills, education, and training).
8. Coordination (e.g., among transportation modes and related industries).
9. Regulations and policies (e.g., environmental regulation and the changing role of governmental identities).
10. Demographics (e.g., population characteristics and land use, including urban/rural differences).
11. Customer needs and expectations.
12. Traffic (e.g., speed, loading, density, and volume).
13. Safety (e.g., work zones and construction).

Research is critical to address the challenges in these technical areas. Transportation stakeholders must be able to:

- Anticipate future issues.
- Explore the potential role of new materials, tools, approaches, and technologies in developing and preserving highway infrastructure.
- Develop guidance on how such materials, tools, approaches, and technologies can enhance system preservation, maintenance, and renewal in response to anticipated challenges.

These new materials, tools, approaches, and technologies concern six *transportation areas*:

1. Highway pavements and materials.
2. Highway bridges and structures.
3. Highway construction.
4. Highway roadside and drainage.
5. Highway traffic services (e.g., signals, intelligent transportation systems, striping, signing, and operations).
6. Highway connectivity to other transportation modes.

Guidance for using these new materials, tools, approaches, and technologies could help transportation agencies better anticipate and deal with the implications of the future.

RESEARCH OBJECTIVE

The objective of this research is to develop guidance for transportation stakeholders for using emerging materials, tools, approaches, and technologies. This guidance will allow stakeholders to deal with long-range (30 to 50 years in the future) highway infrastructure maintenance, preservation, and renewal needs and ensure satisfactory system condition and performance.

RESEARCH SCOPE

Accomplishment of the project objective will require at least the following phases. This interim report covers work accomplished under Phase I of the project.

Phase I: Scenarios and Impacts

This phase has:

- Identified future factors and trends that could significantly influence infrastructure maintenance, preservation, and renewal.
- Assessed the likelihood and impact of various scenarios on future needs.

Research for Phase I is complete and discussed in this interim report.

Phase II: Vision Development

This phase will:

- Identify and examine the potential of new materials, tools, approaches, and technologies to meet future needs for maintaining, preserving, and renewing the highway infrastructure.
- Develop a comprehensive vision for a future, sustainable highway infrastructure.
- Determine potential barriers to the identified materials, tools, approaches, and technologies.

Phase III: Guidance and Communication

This phase will:

- Develop guidance for transportation stakeholders on the use of potential materials, tools, approaches, and technologies for enhancing system maintenance, preservation, and renewal consistent with the described vision.
- Develop communication packages to convey the vision, objective, and products of this research to current and future transportation stakeholders.
- Identify future research efforts necessary to expand the findings of this project and serve as a guide for further research opportunities.

Phase IV: Deliverables

This phase will prepare and submit project deliverables, including a final report that documents the entire research effort, communication packages, and other items identified in the research plan.

OVERVIEW OF RESEARCH PROCESS FOR PHASE I

Research for Phase I of this project is complete and documented in this interim report. This section provides a brief overview of the research process used to meet the Phase I objectives and develop the deliverables for Phase I (namely, this interim report, which includes an updated work plan for Phase II). This process was purposely structured to aid in accelerating the timely completion of Phase I.

The research process was developed based on the use of the scenario planning methodology and to accommodate the breadth of scope characterized by the 13 technical areas referenced earlier in this chapter. A summary of the research process is shown in figure 1.1.

As depicted in figure 1.1, the research process for Phase I had five tasks:

- **Task 1:** Information review.
- **Task 2:** Initial world development.
- **Task 3:** World vetting.
- **Task 4:** Scenario development.
- **Task 5:** Interim report.

The steps taken to fulfill these tasks are numbered consecutively and discussed within each task.

Task 1: Information Review

As shown in figure 1.1, Task 1 included the following steps:

- **Step 1: Review Literature.** The research team conducted the initial literature review prior to a change in principal investigators (PIs). The literature review included 132 publications related to the 13 technical areas.
- **Step 2: Review 20-83 Projects.** This project is part of National Cooperative Highway Research Program (NCHRP) Project 20-83, namely 20-83(03). Researchers reviewed the work completed on the six other 20-83 projects because of their relevance to this project.
- **Step 3: Review the Scenario Planning Methodology.** This review confirmed that scenario planning is the appropriate methodology to assess impacts of certain factors in the 13 technical areas on the 30- to 50-year future time period.

Task 1 is discussed in chapter 2.

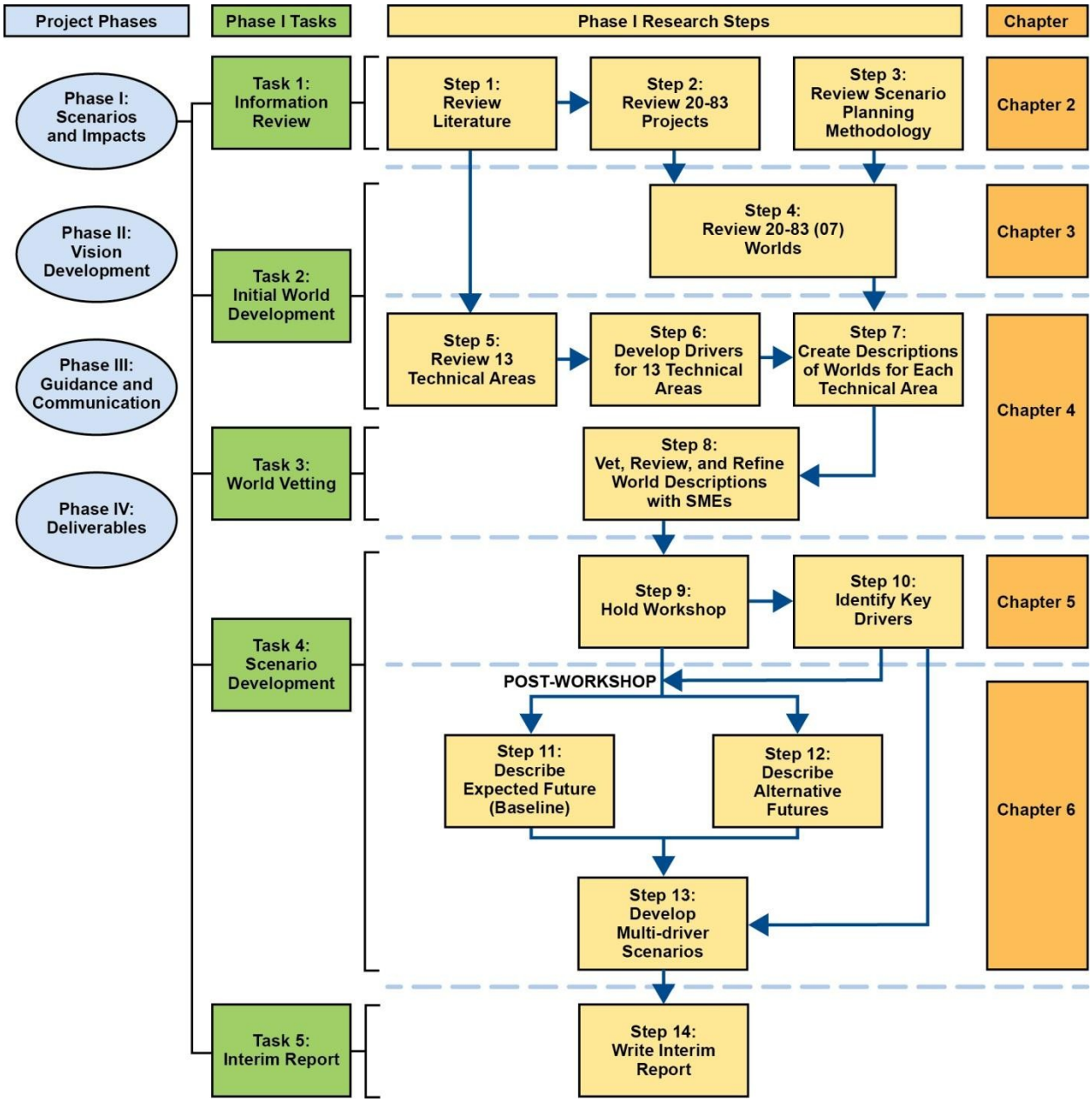

Figure 1.1. Summary of the Research Process.

Task 2: Initial World Development

Task 2 consisted of several steps to create future "worlds" for the 20-83(03) project to use with the 13 technical areas:

- **Step 4: Review 20-83(07) Worlds.** The research team used project 20-83(07), "Sustainable Transportation Systems and Sustainability as an Organizing Principle," as a basis for developing scenarios for the 20-83(03) study. Project 20-83(07) used scenario planning to create six future scenarios, described in that study as "worlds." Based on an evaluation of these six worlds, the research team determined that they provide an

excellent basis for evaluating impacts on the future in the 13 technical areas. The six worlds reflect alternative futures that range from highly negative to highly positive.

- **Step 5: Review 13 Technical Areas.** Based on the initial literature review, the research team performed a detailed study of the 13 technical areas.
- **Step 6: Develop Drivers for the 13 Technical Areas.** Drivers are pertinent characteristics of our world that help us determine the direction in which we are headed. Direction as used here means positive or negative outcomes.
- **Step 7: Create Descriptions of Worlds for Each Technical Area.** Researchers analyzed the impact of these drivers on each of the six worlds under the general context of future maintenance, preservation, and renewal needs 30 to 50 years from now.

Step 4 is discussed in chapter 3, and Steps 5, 6, and 7 are discussed in chapter 4.

Task 3: World Vetting

Task 3 includes **Step 8: Vet, Review, and Refine World Descriptions with Subject Matter Experts (SMEs).** The SMEs reviewed and commented on the viability of the drivers and their impacts on the six worlds. At least two SMEs reviewed the drivers and worlds for each technical area. The research team then refined the drivers and worlds to reflect SME comments. The team also developed a summary-level causal loop diagram to identify a set of overarching drivers and show their relationship to each other based on all 13 technical areas.

Task 3 is discussed in chapter 4.

Task 4: Scenario Development

Tasks 2 and 3 provided the background knowledge for the research team to effectively develop a baseline expected future, alternative futures, and multi-driver scenarios (scenarios incorporating many of the drivers previously determined) reflecting the 30- to 50-year future period. These multi-driver scenarios form the basis for Phase II.

Task 4 included the following steps:

- **Step 9: Hold a Workshop.** The workshop, facilitated by the research team's futurist, included those team members who were involved in creating the drivers and worlds for each of the 13 technical areas. Participants brainstormed the basis for developing multi-driver scenarios.
- **Step 10: Identify Key Drivers.** The output of the workshop resulted in 21 key drivers, representing those drivers that would have the most substantial impact on the future. Also developed in this workshop were characteristics that describe the expected future and alternative futures for each of the 21 key drivers.
- **Step 11: Describe the Expected Future (Baseline).** The research team elaborated on the expected future for each of the 21 key drivers.
- **Step 12: Describe Alternative Futures.** The research team elaborated on the alternative futures for each of the 21 key drivers.
- **Step 13: Develop Multi-driver Scenarios.** The research team prepared multi-driver scenarios in narrative form.

Steps 9 and 10 are discussed in chapter 5, and Steps 11 through 13 are discussed in chapter 6.

The information developed from Task 4 forms the basis for the Phase II assessment of the six transportation areas and future visions/strategies.

Task 5: Interim Report

In **Step 14: Write the interim report,** researchers compiled this document, which includes detailed discussions of Tasks 1 through 4 and provides a Phase II updated work plan.

DEFINITIONS OF TERMS USED IN THIS REPORT

Certain terms take on special meaning in the context of this report:

- **Transportation areas**—specific fields of study in transportation in which to investigate issues in preservation, maintenance, and renewal of the highway infrastructure. The new materials, tools, approaches, and technologies discussed in this project concern these six transportation areas:

  1. Highway pavements and materials.
  2. Highway bridges and structures.
  3. Highway construction.
  4. Highway roadside and drainage.
  5. Highway traffic services (e.g., signals, intelligent transportation systems, striping, signing, and operations).
  6. Highway connectivity to other transportation modes.

- **Technical areas**—general technical disciplines or fields of study—human resources, safety, security, etc.—that can affect preservation, maintenance, and renewal of the highway infrastructure. Challenges discussed in this report result from long-range changes in 13 technical areas:

  1. Technology and innovations (e.g., high-performance materials, construction equipment and methods, and information and monitoring systems).
  2. The environment (e.g., climate change and sustainability).
  3. System performance (e.g., accelerated deterioration and accountability).
  4. Security.
  5. Natural-resource availability (e.g., fuel and construction-material availability).
  6. Finance and budget (e.g., global economics, contracting methods, revenue sufficiency, and costs).
  7. Human resources (e.g., skills, education, and training).
  8. Coordination (e.g., among transportation modes and related industries).
  9. Regulations and policies (e.g., environmental regulation and the changing role of governmental identities).
  10. Demographics (e.g., population characteristics and land use, including urban/rural differences).
  11. Customer needs and expectations.
  12. Traffic (e.g., speed, loading, density, and volume).

13. Safety (e.g., work zones and construction).

- **Drivers**—forces that influence the future; elements that move the plot of the scenario. Drivers are pertinent characteristics of our world that help us determine the direction in which we are headed; direction as used here means positive or negative outcomes. For example, a driver can be adequate funding, which will affect how much capital is invested in new technology. Drivers can also be called uncertainties or forces.

- **Worlds**—an environment shaped to build a comprehensive picture of a possible future and to develop a broad list of uncertainties that exist in each technical area. Project 20-83(07) used scenario planning to create six future scenarios, described in that study as "worlds." The worlds reflect alternative futures that range from highly negative to highly positive:

  1. Crisis World (highly negative).
  2. Dirty World (negative).
  3. Mega World (mid-range).
  4. Suburban World (mid-range).
  5. Wonder World (positive).
  6. Green World (highly positive).

- **Multi-driver scenario**—a hypothetical sequence of events created by multiple drivers. Researchers developed a series of possible futures using a combination of known drivers in the technical areas and plausible alternative trends. The goal is to create baseline expected futures and alternative futures so that transportation agencies can prepare and plan for those possibilities.

- **Baseline expected future**—the most likely scenario to occur compared to any of the others. The expected future focuses on an assessment of the *trend* and *rate* for the driver. The trend indicates direction, and the rate suggests the magnitude of the change in that direction specified. For example, the researcher may identify a trend that suggests positive change in economic growth, but the rate of change will be slow.

- **Alternative futures**—an alternative to the expected future that could plausibly occur instead of the original assumption. The original assumption is that the trend will continue into the future.

Figure 1.2 shows the relationship between some of these key terms.

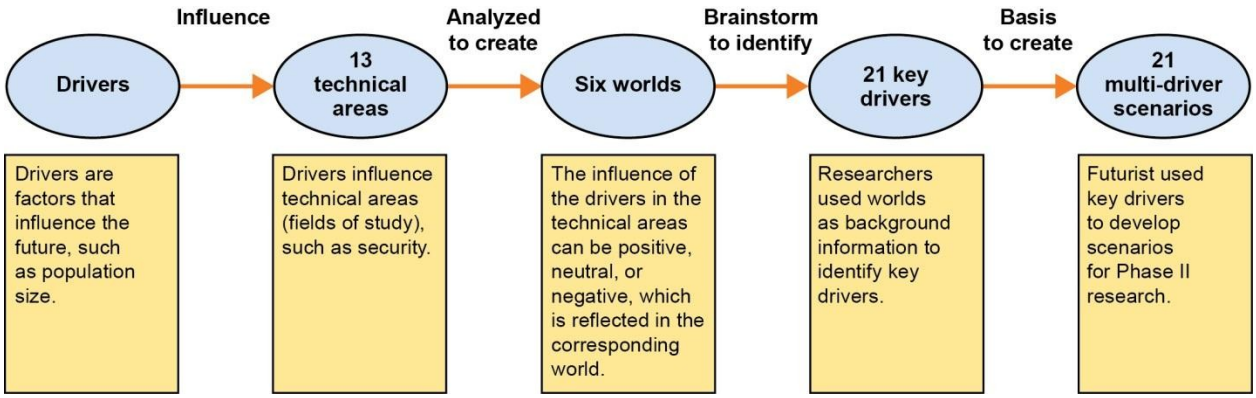

Figure 1.2. Relationship between Key Terms Used in This Report.

CHAPTER 2: INFORMATION REVIEW

Task 1: Information Review provided researchers with background knowledge and served as a starting point to help them analyze the impact of drivers in the 13 technical areas on the future.

Task 1 was based on three steps:

- **Step 1: Review Literature.** The research team conducted the initial literature review prior to a change in PIs. The literature review included 132 publications related to the 13 technical areas.
- **Step 2: Review 20-83 Projects.** This project is part of NCHRP Project 20-83, namely 20-83(03). Researchers reviewed the work completed on the six other 20-83 projects (in both published and unpublished reports) because of its relevance to this project. (The six other research projects are listed at http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2628.) The other projects were further along in their research than this project, and all had completed Phase I of their project effort by March 2011.
- **Step 3: Review the Scenario Planning Methodology.** This review confirmed that scenario planning, with composite scenarios based on multiple drivers, is the appropriate methodology to assess impacts of drivers in the 13 technical areas on the 30- to 50-year future time period.

Figure 2.1 shows the steps for Task 1.

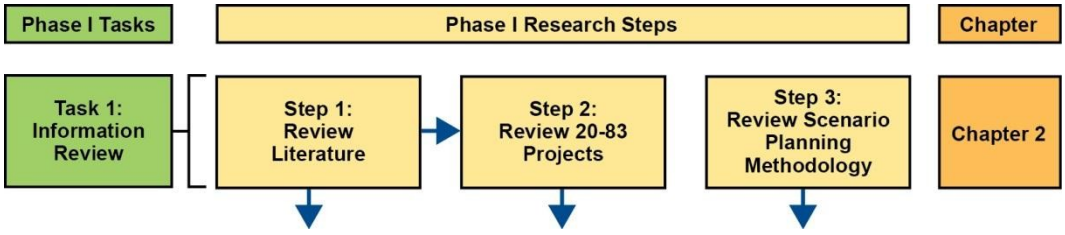

Figure 2.1. Research Process Discussed in Chapter 2.

The Task 1 work occurred on the following timeline:

- Step 1 occurred between July 1, 2010, and November 11, 2010.
- Steps 2 and 3 occurred between March 1, 2011, and April 30, 2011.

GENERAL LITERATURE REVIEW

The initial literature reviews were based on key words associated with the 13 technical areas and furnished by research team members. The Texas Transportation Institute (TTI) librarian conducted this search and provided a list of 389 publications with abstracts to the PI. The list included various types of publications, such as books, journal articles, and magazine articles. The PI then used judgment to determine the value of the proposed publications to this research, based on the publication abstract. This reduced the number of potential publications for review from 389 to 163. The librarian then found and transmitted the available requested publications to the PI.

Of the 163 publications, approximately 132 were reviewed, covering the 13 technical areas specified in the request for proposals (RFP) and listed in table 2.1. The rest of the publications were not reviewed; some were unavailable, while others were not found relevant upon inspection. The research team separated the publications into the 13 technical areas, based on the main focus of each publication. They also identified other related technical areas the publications covered. This action was necessary because the large number of publications required the collective effort of the entire research team. Thus, each team member reviewed 10 or more publications. To provide consistency in the review process, reviewers used a standard format to capture key information from each publication (see appendix A).

Table 2.1. Project 20-83(03) Technical Areas.

No.	Technical Area	Examples
1	Technology and innovations	High-performance materials, construction equipment and methods, and information and monitoring systems
2	The environment	Climate change and sustainability
3	System performance	Accelerated deterioration and accountability
4	Security	Protection from terrorism, piracy, organized crime, illegal drug manufacturing and trafficking, cyber crime, and smuggling
5	Natural-resource availability	Fuel and construction-material availability
6	Finance and budget	Global economics, contracting methods, revenue sufficiency, and costs
7	Human resources	Skills, education, and training
8	Coordination	Coordination among transportation modes and related industries
9	Regulations and policies	Environmental regulation and the changing role of governmental identities
10	Demographics	Population characteristics and land use, including urban/rural differences
11	Customer needs and expectations	Customer need for infrastructure and sustainability, and acceptance of private-sector involvement and user fees
12	Traffic	Speed, loading, density, and volume
13	Safety	Work zones and construction

The main purpose of the reviews was to identify likely changes in the world that would affect future transportation needs. Further, reviewers attempted to identify the probability that the change discussed in the publication would actually happen. Reviewers also attempted to identify the rate at which the likely change would occur as it pertained to the technical area (see appendix A for an example).

In general, this literature review provided minimal information relevant to the future picture of what a technical area might look like 30 to 50 years from now. In fact, the majority of the publications did not provide sufficient information about the technical area to make such assessments. If there was a projection, it typically focused on a five-year timeframe.

Consequently, the research team decided not to summarize those publications associated with each technical area, as is often performed in traditional research studies. The team determined that a literature summary for each technical area would have minimal value. Time was also a consideration. However, the reviews did provide information that was useful in describing the characteristics of each of the 13 technical areas and identifying potential key drivers of the future associated with the area.

REVIEW OF OTHER 20-83 PROJECTS

As this stage, the Phase I reports for the other 20-83 projects were already complete (except for project 20-83 [02], Expediting Future Technologies for Enhancing Transportation System Performance; the PI interviewed a member of the 20-83 [02] research team). The research team obtained these reports in March 2011 through each project's PI. The team reviewed eight documents to determine what type of information the research had developed relevant to the 20-83(03) work.

Table 2.2 shows the other six 20-83 research projects and which of the 13 technical areas they cover. Further, the projects' reports contain a detailed literature review. These reports aided in the development of specific key drivers for those technical areas shown in table 2.1.

Table 2.2. 20-83 Projects and Related Technical Areas in 20-83(03).

Project Number	20-83 Project Name	20-83(03) Technical Area
(01)	Economic Changes Driving Future Freight Transportation	#12—Traffic
(02)	Expediting Future Technologies for Enhancing Transportation System Performance	#1—Technology and innovations
(04)	Effects of Changing Transportation Energy Supplies and Alternative Fuel Sources on Transportation	#5—Natural-resource availability
(05)	Climate Change and the Highway System: Impacts and Adaptation Approaches	#2—The environment
(06)	Effects of Socio-demographics on Travel Demand	#10—Demographics
(07)	Sustainable Transportation Systems and Sustainability as an Organizing Principle for Transportation Agencies	#1—Technology and innovations, #2—The environment, #5—Natural-resource availability, #6—Finance and budget, #10—Demographics, and #12—Traffic

Contents of 20-83 Reports

The research team consulted reports from the other 20-83 projects because their work was relevant to this study. These projects provided relevant information to support the research team's understanding of the 13 technical areas. A brief overview of each project's work is provided in the following subsections.

20-83(01), Economic Changes Driving Future Freight Transportation

Project 20-83(01) seeks to provide "decision makers with a critical analysis of the driving forces behind high-impact economic changes and business sourcing patterns that may affect the US freight transportation system."[1] In the first phase of the project, the team sought to "identify, categorize, and rank the driving forces and critical uncertainties that will influence the future freight transportation flows within the United States over the next 30 years."[2]

The research identified five flow impacts that capture the effect of any driving force on freight flows.[3] The flow impacts include sourcing patterns (freight origin), flow destination (final demand location), routing (product path or mode), flow volume (freight quantity), and value density (freight characteristics). The analysis used input from expert practitioners to develop and estimate the influence of 12 snapshot scenarios. The 12 scenarios contain a diverse set of items but include factors such as an aging domestic population, the empowerment of emerging markets, and technological advancements.[4] Stakeholders and SMEs provided further insight about each scenario, ranking each based on its level of impact and probability of occurrence. The scenarios are further developed in Phase II of the 20-83(01) project.

20-83(02), Expediting Future Technologies for Enhancing Transportation System Performance

The purpose of project 20-83(02) is to discuss different approaches to understanding the impact of future technologies on transportation agencies, and to develop a comprehensive analysis of the future impact of technology.

The 20-83(02) research team found it extremely difficult and inefficient to list and categorize the future technologies that will exist in 30 to 50 years, and that these technologies along with any potential impact would likely be unknown. This was because most of the predictions about future technologies are based on relatively short-term projections. Rather than predicting the unknown future, the 20-83(02) research team found it beneficial to develop a taxonomy and process for agencies to adopt in situating and positioning themselves to profit from potentially new technologies.

During the process of developing a procedure for identifying and adapting future technologies to enhance transportation system performance, the 20-83(02) research team developed a way to catalog different types of future technologies. Future technologies are categorized under five distinctive characteristics: objective, familiarity, implementing party, benefits, and deployment time horizon. In these five main categories, they also identified subcategories of benefits (i.e., safety, efficiency, energy and environmental, quality of life and/or ease of use, and direct agency financial benefits).

20-83(04), Effects of Changing Transportation Energy Supplies and Alternative Fuel Sources on Transportation

The broad objectives of project 20-83(04) are to determine how changes in long-term energy supply and demand will impact state departments of transportation (DOTs), and to develop strategies and actions for DOTs to plan and prepare for the future. The first phase of the project examined "the factors and trends that could influence future energy use in the transportation sector."[5]

The research team divided the analysis into three main dimensions: energy use patterns, travel demand patterns, and relevant policies.[6] The research team expanded these three dimensions and explored 11 research topics. These topics ranged from analyzing future conventional and alternative fuel usage, to investigating population growth, economic growth, and land use and assessing how technological developments will impact energy usage. The research team performed in-depth analyses of the 11 topics to understand the impacts to transportation. The 11 topics are integrated into the scenarios developed in the project's second phase.

20-83(05), Climate Change and the Highway System: Impacts and Adaptation Approaches

Project 20-83(05) seeks to analyze the future impacts of climate change on the United States' highway system.[7] Through several deliverables, the project team will present a comprehensive look at many of the technical aspects of how climate change will impact the future highway system.

The Phase I deliverables present drivers, models, and projections of the effects of climate change at both a national and regional level.[8] The reports cover aspects of climate change that are likely to change in the future, including temperature, precipitation, extreme weather patterns, and sea level. In Phase II, the 20-83(05) research team developed a conceptual model to frame the highway system, described how the projected scenarios are likely to impact the highway system, and reviewed current adaptation practices and methodologies.[9]

20-83(06), Effects of Socio-demographics on Travel Demand

Project 20-83(06) seeks to analyze "the relationships between social and demographic factors and travel demand, and how these relationships might change over time."[10] The project team will use the knowledge developed to inform transportation policy makers and practitioners, and enable them to prepare for likely future changes.

Phase I of the project was comprised of two tasks: establishing a catalog of potential socio-demographic drivers that will impact travel behavior and demand, and "assessing the current best practices for incorporating socio-demographic variables in travel demand forecast models."[10] Phase II refines the work from Phase I, finalizes the catalog of drivers, and establishes the impacts from the drivers.

The 20-83(06) research team developed a large number of drivers and grouped them into seven distinct categories.[11] The seven categories include population growth and size, geo-demographics of population growth and size, household structure and composition, household-based economic activity, cultural and social diversity, external factors with socio-demographics, and external

factors that impact scenario analysis. The research team will use the drivers to develop five or six scenarios in the subsequent project phase.

20-83(07), Sustainable Transportation Systems and Sustainability as an Organizing Principle for Transportation Agencies

Project 20-83(07) seeks to provide a framework for transportation agencies to understand how various economic, social, and environmental demands will interact and shape future needs in the transportation system.[12] The initial report identifies seven drivers that will impact state transportation systems and affect organizing principles. The drivers include population size, characteristics, and distribution; economic growth and public transportation spending; energy; environment and resource use; land use; transportation technology; and the organization of future transportation systems.

The 20-83(07) research team combined the seven drivers to develop six "worlds": Crisis World, Dirty World, Mega World, Suburban World, Wonder World, and Green World.[12] The first two worlds are pessimistic views of how circumstances could change, the second two are moderate, and the final two are optimistic. Each world has varying implications for transportation agencies. These worlds will enable transportation practitioners and agencies to prepare for future demands and understand the challenges posed to creating a sustainable transportation system. In Phase II of the project, the research team will assess the current and future ability of transportation agencies to support a sustainable society.[13]

Comparison of 20-83(03) Technical Areas with Other 20-83 Information

Table 2.3 provides a comparison of the 13 technical areas of project 20-83(03) to the content of other 20-83 project reports:

- Column 1 lists the 20-83(03) technical area.
- Column 2 lists the related 20-83 project document.
- Column 3 lists the page in the document where the information appears.
- Column 4 lists the relevant drivers/issues discussed in the other reports.
- Column 5 lists additional details relative to the 20-83 report drivers/issues in column 4.

Table 2.3 shows that the other 20-83 projects provide a substantial amount of information relevant and useful to this study. These other studies were investigated in developing key drivers for the 13 technical areas and the impact these drivers have on the future worlds described in chapter 4.

Table 2.3. 20-83(03) Technical Areas and Corresponding Drivers/Issues from Other 20-83 Reports.

Technical Area for 20-83(03)	20-83 Report	Page	Driver/Issue	Details
1. Technology and innovations	(01) *Interim Report 1*	16	Personal fabrication	Focuses on the ability of individuals to create their own personal products
	(01) *Interim Report 1*	16	Sensible network	Focuses on the prevalence of sensors on products, vehicles, and infrastructure
	(04) *Phase I Report*	73–89	Plug-in hybrids and battery electric vehicles	Production, distribution, and consumption of electricity; electric-vehicle technologies; factors affecting adoption; plausible future scenarios
	(04) *Phase I Report*	91–106	Hydrogen fuel cell vehicles	Production, distribution, and consumption of hydrogen; hydrogen-vehicle technologies; factors affecting adoption; plausible scenarios
	(04) *Phase I Report*	107–116	Heavy-duty vehicle technologies	Diesel trucks, compressed-natural-gas trucks, liquefied-natural-gas trucks, and hybrid trucks; factors affecting adoption; plausible future scenarios
	(05) *Task 1.2 Report*	8–11	Demographic, land use, and transportation changes	Rehabilitation and reconstruction of existing highways, system expansion, fuel changes and infrastructure needs, and urban congestion
	(07) *Technical Memo 1*	46–48	Transportation and technology	Technical developments in vehicle-based communications, vehicle materials, power systems, and infrastructure
2. The environment	(01) *Interim Report 1*	16	Sustainability regulations	Evaluates the impacts of increased governmental sustainability regulations
	(01) *Interim Report 1*	16	Customer-demanded sustainability	Evaluates the impacts of increased customer-demanded sustainability
	(04) *Phase I Report*	117–127	Climate and energy policies	Corporate Average Fuel Economy (CAFE) standards, vehicle and fuel subsidies, and fuel taxes and subsidies

Technical Area for 20-83(03)	20-83 Report	Page	Driver/Issue	Details
	(05) *Task 1.2 Report*	19–37	Climate impacts to the highway system	Reviews the range of climate impacts on infrastructure and operation/maintenance activities that may require adaptation
	(05) *Task 2.3 Report*	35–72	Adaptation practices and methodologies	Domestic and international adaptation strategies, perspectives, practices, and examples
3. System performance	(05) *Task 1.2 Report*	19–37	Climate impacts to the highway system	Reviews the range of climate impacts on infrastructure and operation/maintenance activities that may require adaptation
4. Security	Not covered	Not covered	Not covered	Not covered
5. Natural-resource availability	(01) *Interim Report 1*	16	Commodity prices and availability	Unpredictable supply and demand levels lead to volatility in the commodities markets
	(04) *Phase I Report*	9–32	Conventional fuels and vehicle technologies	Looks at fuels refined from crude oil and vehicles using an internal combustion engine
	(04) *Phase I Report*	33–55	Natural gas and liquid petroleum gas	Production, consumption, and distribution of natural gas and liquid petroleum gas; adoption of natural gas and liquid petroleum gas; plausible future scenarios
	(04) *Phase I Report*	57–71	Biofuels	Production, distribution, and consumption; biofuel-powered vehicle technologies; factors affecting adoption; plausible future scenarios
	(07) *Technical Memo 1*	38–41	Energy	Future patterns of energy use and future transportation fuel prices
6. Finance and budget	(01) *Interim Report 1*	15	Global trade	Interdependence of countries, volatility of markets, and impacts to gross domestic product (GDP)
	(01) *Interim Report 1*	15	Emerging markets	Emerging markets grow, the dollar and euro decrease in power, and emerging powers focus on importing and not exporting

Technical Area for 20-83(03)	20-83 Report	Page	Driver/Issue	Details
	(01) *Interim Report 1*	16	Commodity prices and availability	Unpredictable supply and demand levels leads to volatility in the commodities markets
	(01) *Interim Report 1*	16	Protectionism	How increasing protectionism will impact freight movement
	(04) *Phase I Report*	129–159	Transportation finance and investment	Historical trends, interactions with other variables and scenario factors, and future scenarios
	(04) *Phase I Report*	167–173	Economic growth	Economic trends, interaction of economic growth and transportation, and future scenarios
	(07) *Technical Memo 1*	31–37	Economic growth and public-sector spending	Future patterns of economic growth and public-sector spending on transportation
	(07) *Technical Memo 1*	50–57	System funding, operation, and control	How future transportation systems will be organized and the role of the different players in the process
7. Human resources	(07) *Technical Memo 1*	N/A	Staffing levels	The scenario descriptions contain brief discussions of how staffing and human resources will be impacted in transportation agencies under various situations
8. Coordination	(01) *Interim Report 1*	16	Protectionism	How increasing protectionism will impact freight movement
	(07) *Technical Memo 1*	50–57	System funding, operation, and control	How future transportation systems will be organized and the role of the different players in the process
9. Regulations and policies	(01) *Interim Report 1*	15	International climate regulations	How international climate regulations will impact freight movement
	(01) *Interim Report 1*	16	Protectionism	How increasing protectionism will impact freight movement
	(01) *Interim Report 1*	16	Sustainability regulations	How increased sustainability regulations will impact freight movement
	(04) *Phase I Report*	117–127	Climate and energy policies	CAFE standards, vehicle and fuel subsidies, and fuel taxes and subsidies

Technical Area for 20-83(03)	20-83 Report	Page	Driver/Issue	Details
	(07) *Technical Memo 1*	31–37	Economic growth and public-sector spending	Future patterns of economic growth and public-sector spending on transportation
10. Demographics	(01) *Interim Report 1*	15	Aging of the U.S. population	Focuses on the impacts to freight movement of an aging U.S. population
	(04) *Phase I Report*	161–166	Population growth	Population trends, regional differences in population trends, interaction of population growth and transportation, and future population scenarios
	(04) *Phase I Report*	173–182	Land use patterns	Land use trends, interaction of land use and transportation, and future land use scenarios
	(05) *Task 1.2 Report*	1–11	Demographic, land use, and transportation changes	Projected demographic changes, projected changes in land use patterns, and potential changes to transportation systems and technology
	(06) *Interim Report*	13–24	Demographics and travel behavior	Relationship between demographics and travel behavior, age effects, gender, race, education, income, employment status, and household size
	(07) *Technical Memo 1*	25–30	Population size, distribution, and characteristics	The size, distribution, and characteristics of the U.S. populations
	(07) *Technical Memo 1*	48–49	Land use	The use and modification of land to support people activities
11. Customer needs and expectations	(01) *Interim Report 1*	N/A	N/A	The movement of freight and goods could be a customer of the U.S. highway system; the research in this report on how freight needs will change may bear some significance and be worth further scrutiny
12. Traffic	(01) *Interim Report 1*	N/A	N/A	The entire report focuses on how various trends will impact the movement of freight; this directly impacts traffic levels

Technical Area for 20-83(03)	20-83 Report	Page	Driver/Issue	Details
	(04) *Phase I Report*	205–214	Variables that will influence travel demand	Annual energy outlook projections, total passenger and goods movement, mode split for passenger travel, and mode split for goods movement
	(06) *Interim Report*	10–24	Travel demand forecasting	Review of travel demand; regional, statewide, strategic, and land use models
	(06) *Interim Report*	25–34	Emerging issues that impact travel demand	Oil and climate change, telematics, long-distance travel, high-speed rail, and commercial and freight travel
13. Safety	Not covered	Not covered	Not covered	Not covered

OVERVIEW OF SCENARIO PLANNING METHODOLOGY

The scenario planning methodology is a strategic planning method that organizations use to make flexible long-term plans. It recognizes that many variables may combine in complex ways to create unexpected futures. By building expected and "alternative" futures, organizations can evaluate possible scenarios in advance and then devise measures to minimize the negative impacts and build on opportunities.

The following questions can be addressed through the scenario planning methodology:

- What are the key influential factors of the system?
- How can the system thrive under various possible future conditions?
- What are the early signals indicating the likelihood of dominance for certain scenarios?
- What are the strategies to mitigate possible risks associated with dominating scenarios?

Scenario planning includes various recommended steps, such as those described by the Federal Highway Administration (FHWA) and Peter Schwartz.

FHWA has prepared a *Scenario Planning Guidebook* to assist transportation agencies with implementing the scenario planning methodology.[14] The framework created by FHWA covers six phases:

- **Phase 1:** Identify objectives and necessary resources.
- **Phase 2:** Collect the data to understand the area of interest. This phase establishes a baseline analysis.
- **Phase 3:** Define organizational goals.
- **Phase 4:** Create baseline and alternative scenarios based on the previous phases.

- **Phase 5:** Analyze the impacts of the scenarios.
- **Phase 6:** Combine the various scenario impacts and organizational goals to develop a comprehensive vision.

Peter Schwartz, the president of the Global Business Network, is a pioneer in the field of scenario planning. The following procedures are recommended in his book, *The Art of the Long View:*[15]

- **Step 1:** Identify the goals and tasks involved.
- **Step 2:** Gather information to develop further understanding of the issue at hand.
- **Step 3:** Identify the driving forces that influence the factors or areas identified in the previous step.
- **Step 4:** Rank factors and driving forces by importance and uncertainty.
- **Step 5:** Filter the factors and forces to identify the most important critical uncertainties.
- **Step 6:** Narrow down to two or three fully detailed descriptions of scenarios that best capture the dynamics of the situation.
- **Step 7:** Explore the implications and define appropriate responses to each of the scenarios.
- **Step 8:** Formulate a guiding strategy to monitor the system.

Both planning approaches follow a generic approach to understanding the area; defining the immediate environment, key forces, and uncertainties around these forces; and analyzing the implications and developing strategies for the future. The research team concluded that scenario planning was an acceptable methodology for creating future worlds and then multi-driver scenarios in Phase I. Scenario planning will be used in Phase II to develop visions/strategies for future transportation needs.

SUMMARY

This chapter focuses on information review to support using scenario planning for the 20-83(03) study. The information review covered 132 publications and six other 20-83 projects. These projects provided relevant information to support the research team's understanding of the 13 technical areas. Scenario planning was selected as the main research methodology for guiding the Phase I and Phase II efforts.

The outcomes of this information review will be used in chapters 3 and 4 as a starting point to analyze the impact of drivers in the 13 technical areas on the future.

CHAPTER 3: USE OF SCENARIO PLANNING IN TECHNICAL AREA ASSESSMENTS

Task 2: Initial World Development aims to create worlds, an environment shaped to build a comprehensive picture of a possible future and to develop a broad list of uncertainties that exist in each technical area. Discussion of Task 2 occurs in this chapter and chapter 4.

This chapter focuses on Step 4: Review 20-83(07) Worlds. This step provides the basis for the evaluation and assessment of the 13 technical areas in terms of their impact on the future as related to transportation and in particular maintenance, preservation, and renewal. The step also includes the rationale for the approach followed, the scenario planning methodology. The primary input to Step 4 is the review of the other 20-83 project reports (Step 2) and the decision to use the scenario planning methodology (Step 3).

Figure 3.1 shows Step 4, part of Task 2.

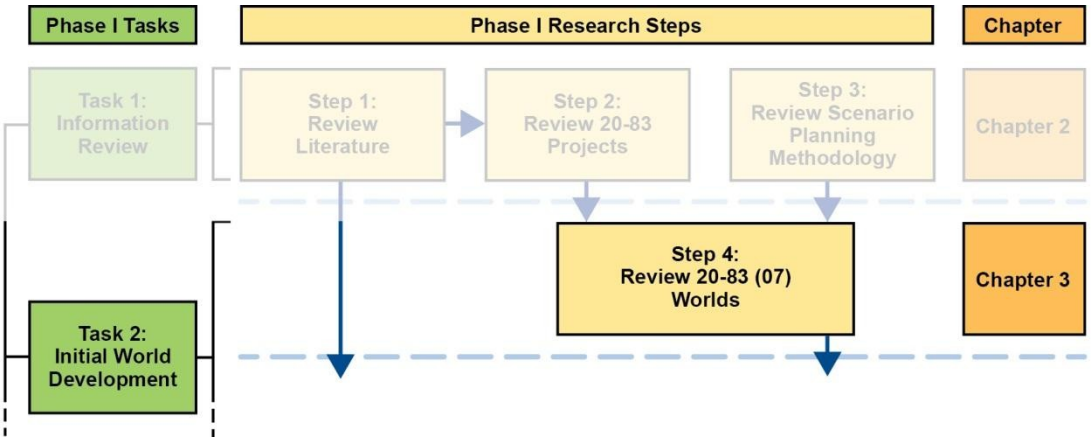

Figure 3.1. Research Process Discussed in Chapter 3.

GENERAL BASIS FOR TECHNICAL AREA ASSESSMENTS

Project 20-83(07) as a Building Block

In Task 1, the research team performed a detailed review of the other 20-83 research projects. The 20-83(07) project, Sustainable Transportation Systems and Sustainability as an Organizing Principle for Transportation Agencies, had the closest fit with the 20-83(03) project. The team concluded that this study would substantially benefit from using Phase I *Technical Memorandum 1* from project 20-83(07) to guide the development of the future impact of this project's 13 technical areas.

The objective of the 20-83(07) research is to provide a framework for transportation agencies to identify and understand the future trends and external forces that will increasingly put pressure on their ability to carry out their responsibilities, including meeting society's evolving demand for transportation services and meeting society's emerging need to operate on a more sustainable basis. The framework also provides a means for agencies to assess their future capacity to meet society's demands, and to provide or identify tools and approaches that agencies may use to

assist in making changes deemed appropriate and necessary to meet rapidly changing needs and conditions.

The 20-83(07) study employed a scenario planning methodology similar that presented in FHWA's guide to scenario planning, briefly discussed in chapter 2. The process used in 20-83(07) included the following steps:

7. Establish the scope, key assumptions, and review of "straw man" drivers and scenarios.
8. Conduct an in-depth scan of literature and interviews with SMEs.
9. Identify and analyze drivers.
10. Synthesize and integrate drivers to create scenarios.
11. Review, refine, and revise scenarios through discussions, interviews, and inputs from SMEs.
12. Finalize scenarios and determine challenges and opportunities for state transportation agencies (STA).

Drivers and Technical Areas Developed in 20-83(07) and 20-83(03)

As shown in table 3.1, columns 1 and 2, the 20-83(07) research team developed drivers from seven technical areas using the literature and expert opinion. The technical areas were described using a common set of subheadings:

- Description.
- Significance.
- Trends.

Of these three subheadings, the trends material was very comprehensive in its content. The focus of the trends was on mega-trends that will impact the technical areas 30 to 50 years from now. For example, one 20-83(07) technical area is "population size, characteristics, and magnitude." The significance of this trend is that "The size, geographic distribution, and characteristics of the US population are likely to be a major factor influencing the resources available to state transportation agencies, transportation demand, and opportunities and challenges facing state transportation programs." Specific trends include projected population growth given certain assumptions, the distribution of the population in likely emerging mega-regions, and potential outcomes related to population based on projections of size by low, medium, and high. A type of outcome would be the impact on economic growth, for example.

As shown in table 3.1, column 3, five of the 20-83(03) technical areas are directly related to the 20-83(07) technical areas. The 20-83(07) project only covers sustainability, so the other 20-83(03) technical areas were outside its scope. The 20-83(07) work provides a solid basis for developing drivers for this study, and the research team used other information from the literature review to fill in any gaps.

(This report uses terminology as defined in project 20-83 [03] for understandability. Some terms between 20-83[03] and 20-83[07] differ.)

Table 3.1. Technical Areas from 20-83(07) That Correspond to Technical Areas from 20-83(03).

Technical Area from 20-83(07)	Definition	Technical Area from 20-83(03)
Population size, characteristics, and distribution	The size, distribution, and characteristics (e.g., age, sex, and ethnicity) of the U.S. population	#10—Demographics
Economic growth and public transportation spending	Future patterns of economic growth (e.g., GDP, inflation, investment, employment, and income growth) and public-sector spending (e.g., federal, state, and local) on transportation	#6—Finance and budget
Energy (including transportation fuel sources and price)	Future changes in energy use and the proportion of energy derived from different sources; includes the price and fuel sources used by modes of transportation	#5—Natural-resource availability
The environment and resource use	Future changes in the environment (in particular, climate change), resource availability, and resource use	#2—The environment and #5—Natural-resource availability
Land use	Population distribution, demographics, land use patterns, and development factors	#10—Demographics
Transportation technology	The development of future transportation technologies and the degree to which these technologies are adopted by individuals and networks	#1—Technology and innovations
Organization of future transportation system (i.e., funding, privatization, and centralization/ decentralization)	The funding, degree of privatization, and the centralization/decentralization (i.e., the roles of federal, state, regional, and local governments)	#6—Finance and budget

Note: Columns 1 and 2 are found on page 22 of *Technical Memorandum 1* of project 20-83(07). Also note that only five of 13 technical areas match up with the 20-83(03) project.

Worlds as a Setting for 13 Technical Areas

In the 20-83(07) study, the drivers in the seven technical areas were used to formulate six "world" scenarios, as shown in figure 3.2. The 20-83(03) research team determined that these six worlds would provide a good general basis for developing worlds for this study.

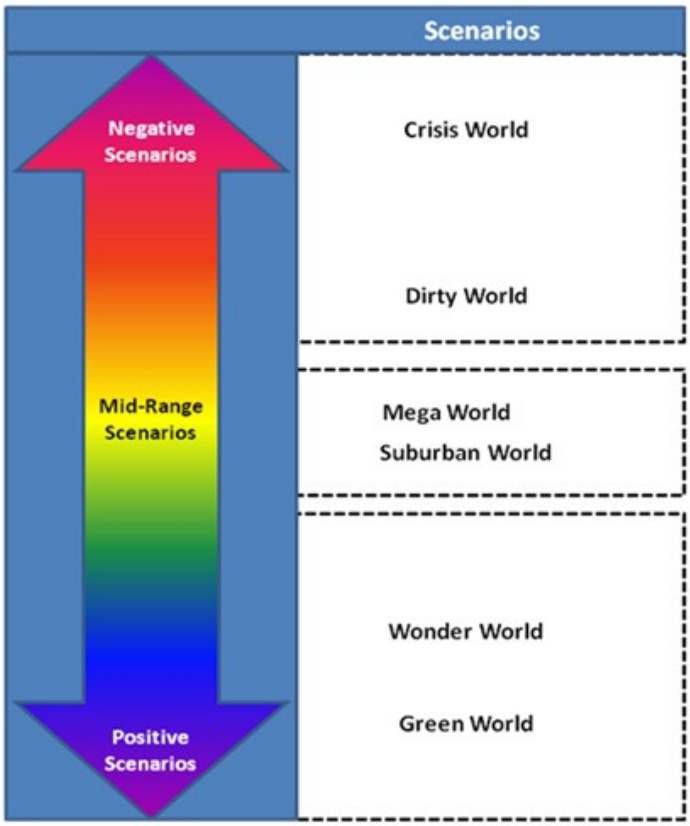

Figure 3.2. Scenarios from 20-83(07) *Technical Memorandum 1*.[16]

The following is a brief description of the 20-83(07) worlds:

- **Crisis World:** Slow technology, slow growth, high resource price, rapid climate change; therefore changing urban form and public commitment to sustainability.
- **Dirty World:** Crisis World but less negative.
- **Mega World:** Extrapolation of current trends with more concentration in urban centers.
- **Suburban World:** Mega World with movement to suburbs and second-tier cities.
- **Wonder World:** High technology, high growth, and distributed population.
- **Green World:** High growth but sustainably, more restriction, and less individual freedom and choice.

Appendix B provides a more detailed description of the six world scenarios from the 20-83(07) study.

DEVELOPMENT OF 20-83(03) DRIVERS AND WORLDS

The Phase I results of the 20-83(07) study align very well with the Phase I requirement to develop scenarios for this study. The 20-83(03) research process also followed a similar path compared to 20-83(07) to developing the Phase I worlds. A summary of the steps followed appears in figure 1.1 in chapter 1, and the steps themselves are described more fully in chapter 4.

As explained in the previous section, 20-83(07) used scenario planning, based on FHWA's *Scenario Planning Guide* and Schwartz's *The Art of the Long View,* for steps to develop scenarios. The 20-83(07) project, while having a different focus than the 20-83(03) project, developed key drivers in seven technical areas as a basis for proposing six worlds (see figure 3.2). The 20-83(03) research team reviewed the drivers and technical areas and found that seven technical areas were similar to five of the 13 technical areas covered under this project. Further, the 20-83(07) study provided additional information on other technical areas, as shown in table 2.3.

Upon examining the six 20-83(07) worlds, the research team's conclusion was that these six worlds provide an excellent high-level picture of the future (30 to 50 years) from a negative perspective to a very positive perspective. The team deemed the six worlds adequate for developing plausible worlds for each of the 13 technical areas. The research team also determined that the worlds created for each technical area should consider maintenance, preservation, and renewal of infrastructure but without substantial detail. Details regarding the future in infrastructure will be covered in Phase II. Finally, the technical area worlds were not intended to be the final deliverable of this project phase. The development of these worlds served as a stepping stone for developing the multi-driver scenarios described in chapters 5 and 6.

SUMMARY

This chapter presents details from Project 20-83(07). The research team determined that the 20-83(07) project was a sound basis for assessing the impact of the 13 technical areas on the six worlds from that study. The 20-83(07) study also provided detailed insights into five technical areas of 20-83(03). The output of chapter 3 is used in chapter 4.

CHAPTER 4: WORLDS

The content of this chapter forms the basis for developing multi-driver scenarios in chapters 5 and 6. As such, chapter 4 serves as a database of information that aided the research team in building a detailed knowledge base reflecting the impact of the drivers in the 13 technical areas on the future. Chapter 4 does not provide multi-driver scenarios but only facilitates the development of those scenarios as discussed in the next two chapters.

This chapter focuses on steps from the following tasks:

- Task 2: Initial World Development aims to create worlds, an environment shaped to build a comprehensive picture of a possible future and to develop a broad list of uncertainties that exist in each technical area. Discussion of Task 2 occurs in chapter 3 (Step 4) and this chapter (Steps 5, 6, and 7).
- Task 3: World Vetting (Step 8) aims to have SMEs refine the world descriptions.

This chapter discusses the following steps:

- **Step 5: Review 13 Technical Areas.** Based on the initial literature review, the research team performed a detailed study of the 13 technical areas.
- **Step 6: Develop Drivers for the 13 Technical Areas.** Drivers are pertinent characteristics of our world that help us determine the direction in which we are headed. Direction as used here means positive or negative outcomes.
- **Step 7: Create Descriptions of Worlds for Each Technical Area.** Researchers analyzed the impact of these drivers on each of the six worlds under the general context of future maintenance, preservation, and renewal needs 30 to 50 years from now.
- **Step 8: Vet, Review, and Refine World Descriptions with SMEs.** The SMEs reviewed and commented on the viability of the drivers and their impacts on the six worlds. At least two SMEs reviewed the drivers for each technical area. The research team then refined the drivers and worlds to reflect SME comments. The team also developed a summary-level causal loop diagram to identify a set of drivers and show their relationship to each other based on all 13 technical areas.

Figure 4.1 shows the steps discussed in this chapter.

ASSESSMENT APPROACH

This section explains the approach followed to assess the future impact of the drivers in the 13 technical areas (listed in table 2.1) based on the six worlds from the 20-83(07) study.

Inputs to Task 2

As depicted in figure 4.1, the key inputs to Tasks 2 and 3 are the results of the information review covered in Task 1 and discussed in chapter 2. This input includes information from the review of publications documented early in the project and information derived from the other 20-83 projects that were specifically relevant to this project. In addition, selecting the scenario planning methodology to guide the assessment of the 13 technical areas resulted in the use of the 20-83(07) worlds to support the analysis of the 13 technical areas presented in this chapter.

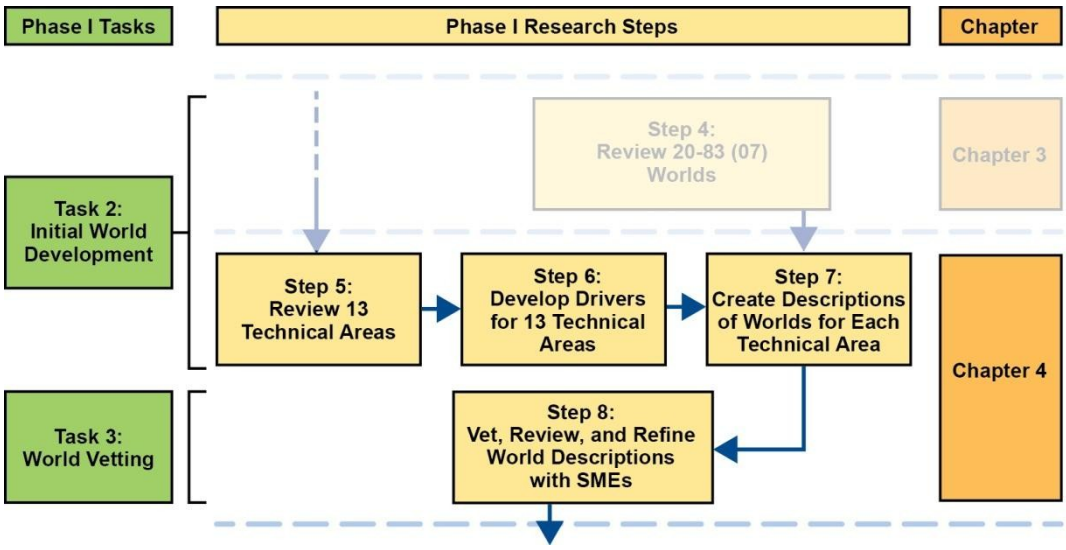

Figure 4.1. Research Process Discussed in Chapter 4.

Creating Descriptions of Technical Areas, Key Drivers, and Worlds

The decision to use the 20-83(07) worlds was important because:

- The six worlds provided a consistent basis for the research team to assess each of the 13 technical areas.
- The six worlds provided insight into the characteristics of scenarios developed using the scenario planning methodology.
- The approach helped expedite the assessment and analysis of the future impact of the drivers of the 13 technical areas.

Six members of the research team developed the worlds for each technical area. They each followed slightly different approaches to develop the content for their technical areas, often based on their expertise in the area coupled with more specific information acquired through the review of additional publications not covered in the literature review, Internet searches, and government documents. Thus, the content of a world may be expressed differently for a specific technical area. However, each world was consistently described in terms of three sections:

- **Overview:** general characteristics of the technical area.
- **Key drivers:** forces that impact each technical area. The research team described the impact of the drivers in each technical area on the future 30 to 50 years out from 2011.
- **Six worlds:** plausible future worlds for the technical area using the six worlds described in project 20-83(07).

The level of detail in the world descriptions was greater than in the 20-83(07) study but did not provide details specific to maintenance, preservation, and renewal. These specific details will be covered in Phase II in relation to the six transportation areas (discussed in chapter 1). The full narrative description of each technical area is included in appendix C.

Vetting, Reviewing, and Refining World Descriptions

Because a small number of research team members developed the 13 technical areas, SMEs then needed to vet the individual area drafts. SMEs included the team's two consultants and 25 other SMEs within TTI with expertise in a specific technical area. External SMEs were not used in this case because the request for vetting was made with the intent of not charging time to the project. Also, the research team concluded that sufficient in-house expertise was available in all technical areas.

The intent of this SME review was to determine if gaps or missing information was present in the world descriptions. This review considered both the drivers for each technical area and how these drivers impacted the six worlds for that technical area. Each SME considered the following questions:

- Are there any gaps in the material? Any fatal mistakes or omissions? Anything that is not properly or adequately characterized based on your knowledge of the technical area?
- Is there anything in the content that does not make sense? Are the author's descriptions of the six 20-83(03) worlds plausible in relation to the technical area content?
- Are there key references or resources that you can provide on this technical area?

In addition, the SME received a background memo, along with draft descriptions of the technical areas and their worlds, that provided information on both the 20-83(03) and 20-83(07) projects. The SME was asked to provide a written response, and discussions with each SME helped clarify their points. The 13 technical area descriptions were revised based on SME input and discussions among the research team members.

The author of the technical area then consolidated the narrative descriptions into a two- or three-page format providing only key information. The key information includes a brief overview of the technical area, three to five key drivers for that technical area, and the impact of each driver on the six worlds in regards to that technical area. This format is followed for each area and is covered in the following subsections. Appendix C provides a more complete treatment of the technical areas.

TECHNICAL AREA: TECHNOLOGY AND INNOVATIONS

Overview

The development of technology will impact transportation in various ways. Technology can radically change the practice of maintenance, preservation, and renewal of highway infrastructure by reducing deterioration with better predictive tools, by providing alternative transportation options, by increasing the durability of construction materials, and by reducing traffic-related crashes.

Key Drivers

The drivers for developing and implementing new technologies are described in Table 4.1.

Table 4.1. Key Drivers of Technology and Innovations.

Key Driver	Description
Demand for efficiency and capacity	• Requires optimal movement of people and transportation of goods • Will increase due to the inability to expand capacity • Increase in demand for efficiency and capacity will lead to investigating technologies such as intelligent vehicles, innovative public transportation systems, and new materials
Demand for safety measures	• Requires actions to protect motorist and pedestrians from accidents • Will increase as the transportation network becomes more sophisticated and complex • Increase in demand for safety measures will lead to investigating technologies such as better traffic-monitoring systems, innovative construction/safety equipment/devices, and intelligent vehicles
Demand to meet legal and regulatory requirements	• Includes federal, state, and international regulations • Will change how private industries conduct business and will encourage them to invest in technologies tailored to meet these requirements • Stringent environmental regulations may lead to investigating electric or hybrid vehicles, innovative construction practices, and new materials
Adequate funding	• Provides the capital necessary to invest in and develop new technology • Can be provided by both public and private sector

Six Worlds

Table 4.2 shows how key drivers impact the future of technology and innovations as they move from the most negative world (Crisis) to the most positive world (Green).

Table 4.2. Key Drivers and Their Impacts on the Future of Technology and Innovations in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Demand for efficiency and capacity	No, poor economic conditions lead to focusing more on basic needs	Slight increase in demand for efficiency leads to interest in new technology	High demand for efficiency and capacity leads to strong support for new technology	Slight decrease in demand for efficiency and capacity leads to minor support for new technology	Moderate demand for efficiency and capacity leads to modest investment in new technology	Moderate demand for efficiency and capacity leads to modest investment in new technology
Demand for safety measures	No, people are more concerned with basic needs	Slight increase in demand for transportation safety leads to investigating new technology	High demand for safety measures leads to strong support for new technology	High demand for safety measures leads to strong support for new technology	Slight decrease in demand for transportation safety leads to modest investment for new technology	No, technology prevents accidents and eliminates the demand for safety measures
Demand to meet legal and regulatory requirements	No, government has not set a comprehensive enforcement in place yet	Slight increase in demand to meet regulations leads to interest in new technology	Moderate increase in demand to meet regulations leads to continued increase in support for new technology	High demand to meet regulations leads to strong support for new technology	No, advancement in technology eliminates the demand to meet regulations	Stringent government regulations lead to moderate increase in demand to meet regulations and support for new technology
Adequate funding	No, funding is not available to support new technology	Small amount of funding is available for investigating new technology	Fair amount of funding is available for developing new technology	Fair amount of funding is available for adopting new technology	Adequate funding is available for advancement of technology	Substantial funding is available for advancement of technology

TECHNICAL AREA: THE ENVIRONMENT

Overview

Environmental requirements and changes in the environment are critical factors that must be considered by state transportation agencies in the 21st century. The enforcement of environmental policies and regulations can often be challenging for state transportation agencies. The construction, operation, and preservation of highways place a burden on natural resources and environmental quality; transportation agencies must incorporate these concerns into their decision making and implementation process. Regulations and green construction methods influence the practices in the construction, maintenance, and preservation of highways. They can change a project's costs, completion time, siting, materials, and methods. The effects of climate change will also impact these same areas.

Key Drivers

The drivers for the environmental technical area are described in table 4.3.

Table 4.3. Key Drivers of the Environment.

Key Driver	Description
Policy and regulation	• Increases or decreases in environmental regulations at the federal, local, or state level can impact project costs, delays, coordination, materials, processing, and manufacturing
Environmental quality	• Air quality, greenhouse gases, water quality, and noise control can impact project costs, delay, materials, processing, and manufacturing • The construction of highways can directly impact the environmental quality of a region
Green construction	• An increasing focus on sustainable development and conservation can impact the selection of project materials, construction methods, costs, and siting • Green construction places a greater emphasis on increasing the operation life of facilities
Climate change	• Climate change describes the increases in temperatures due to greenhouse gases and the resulting effects, like changes in precipitation and sea level • These changes will alter the way state agencies construct roads and locate and design facilities

Six Worlds

Table 4.4 shows how key drivers impact the future of the environment as they move from the most negative world (Crisis) to the most positive world (Green).

Table 4.4. Key Drivers and Their Impacts on the Future of the Environment in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Policy and regulation	Medium impact. They are alternately strict and relaxed as the nation cannot meet regulatory standards due to the economy.	Medium impact. Effects of climate change are not pronounced, so regulation is not as important.	High impact. Regulations and policies continue at current rates.	High impact. Regulations and policies continue at current rates.	High impact. Regulations and policies continue at current rates.	Very high impact. Drastic increases in policy and regulations affect state DOT business models.
Environmental quality	Low impact. Not successful due to other, more pressing concerns.	Medium impact. The methods that are cost effective receive attention.	Medium impact. Progress is made in reducing greenhouse gases (GHGs) and improving air and water quality.	High impact. Progress is made in reducing GHGs and improving air and water quality.	Very high impact. Progress is made in reducing GHGs and improving air and water quality and noise control.	Very high impact. Significant progress is made in reducing GHGs and improving air and water quality and noise control.
Green construction	Low impact. Not successful due to other, more pressing concerns.	Medium impact. The methods that are cost effective receive attention.	Medium impact. Construction alternatives are slowly adopted.	Medium impact. Construction alternatives are slowly adopted.	Very high impact. Considerable progress is made in green construction.	Very high impact. Considerable progress is made in green construction.
Climate change	High impact. Changes are worse than expected, and significant natural disasters occur.	Low impact. Crises related to climate change do not occur.	Medium impact. Changes occur at expected rates.	Medium impact. Changes occur at expected rates.	Medium impact. Changes occur at expected rates and are mostly manageable.	Medium impact. Changes occur at expected rates and are manageable.

TECHNICAL AREA: SYSTEM PERFORMANCE

Overview

The performance of transportation as a system depends on a number of key drivers. Although a basic aim would be to have a system capacity slightly greater than the demand on that system, this is rarely realized. The factors affecting this imbalance are generally the lag time between capacity expansion and general growth demand arising from population growth, and the lack of capital, which is often earmarked for more urgent social concerns. Moreover, a huge regulatory burden often weighs down progress and implementation of new projects.

Thus, it is often easier to maintain the existing infrastructure. And while the interstate system has generally been well kept and maintained, the quality of regional infrastructure and transportation services has historically been somewhat spotty. This is largely due to regional and state politics that may not be concordant with a national view.

Naturally, two of the key drivers in keeping the performance of the transportation system as a whole in a state of balanced equilibrium will be the interplay between maintenance of the existing system and the expansion of that system, or even creation of newer systems. Much of this state of equilibrium depends on vehicles for financing both major and minor projects.

Technology also has the potential for tremendous changes in years to come because it promises to enhance capacity and safety.

Key Drivers

The drivers for system performance are described in table 4.5.

Table 4.5. Key Drivers of System Performance.

Key Driver	Description
Infrastructure maintenance	• Depends largely on the health and well-being of the local state and county tax base; this becomes the default necessity if infrastructure expansion is stifled • The interplay between maintenance and renewal will depend on the labor cost and the degree of mechanization that can be used to automate menial maintenance tasks
Infrastructure expansion	• Depends on the ability to fund huge megaprojects, either by public-private partnerships (PPPs) or by tax incentives, direct taxation, or national deficit financing • Land cost and eminent domain powers will markedly affect expansion
Land availability for infrastructure	• Interdependent on population growth: if urban centers grow, land availability for infrastructure expansion is limited • If suburban populations expand, low-priced land tends to be plentiful • Problems with eminent domain acquisition persist
Energy	• Energy efficiency needs to be incentivized either by governmental oversight and regulation • Supply and demand of energy pricing, particularly oil and gas, are affected by a combination of world conditions and domestic policy for drilling, exploration, and distribution • The use of alternative modes of transportation (air, rail, and sea versus road) is governed by oil pricing
Vehicle technology	• Vehicle technology is affected by the age of the fleet and the affordability of new technology in new vehicles • Technology will lead to enhanced in-vehicle safety features • Technology will lead to improved highway capacity via automatic routing and traffic control • Autonomous vehicles of the future promise to improve both safety and capacity

Six Worlds

Table 4.6 shows how key drivers impact the future of system performance as they move from the most negative world (Crisis) to the most positive world (Green).

Table 4.6. Key Drivers of System Performance and Their Impact in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Infrastructure maintenance	Failures commonplace. Maintenance restricted to essential and emergency repairs.	Patch and repair preferred method of pavement and bridge maintenance.	Infrastructure maintained and renewed as required, but not expanded.	Infrastructure maintained and renewed as required, but expanded only slowly.	Good money supply leads to PPP maintenance arrangements.	Government maintenance through user-pays and taxation.
Infrastructure expansion	Insufficient capital for any expansion. Infrastructure is limited to maintenance only.	Capital limited. Modest expansion, with low-cost and low-quality materials.	Capital adequate. PPP arrangements expand interstate system within mega-regions.	Capital adequate. PPP arrangements expand interstate system around main cities.	Private sector leads expansion of infrastructure assets.	New expensive guideways implemented by government sector.
Land availability for infrastructure	Land use uncontrolled but mostly unaffordable due to lack of capital for purchase.	Land use uncontrolled and available.	Suburban sprawl controlled and limited, but land sufficient for infrastructure expansion. Expansion of infrastructure in cities constricted.	Old urban centers decay. Cities are partly abandoned. Some land is available for arterial routes. Rural land is inexpensive and leads to further sprawl.	Laissez-faire zoning leads to mix-use land and infrastructure. Land is a sound investment.	Strictly controlled zoning and land use patterns emerge. Governments buy land for infrastructure projects.
Energy	Gas/diesel main fuels at high prices (~$9/gallon) and worldwide shortages.	Gas/diesel main fuels. Prices high (~$8/gallon) due to road taxes.	Some hybrid vehicles exist but mostly a conventional fleet (~$7/gallon).	20% of fleets hybrid-electric. Remainder conventional (~$5/gallon).	Hybrid gasoline and diesel-electric are the norm. Price (~$6/gallon) forces innovation.	Light vehicles and cars hydrogen and fuel cell. Some diesel legacy vehicles remain (~$10/gallon).
Vehicle technology	Vehicle fleet is aged due to lack of imports. New vehicles limited mostly to military and security fleets.	Vehicle fleet is aged due to lack of imports. New vehicles limited mostly to corporate fleets.	New technologies abound but are cost prohibitive to implement except on public-sector city fleets.	New technologies abound but are cost prohibitive to implement except on limited public-sector fleet.	Private sector leads developments, including autonomous vehicle fleet.	Government mandates high-efficiency guideways.

TECHNICAL AREA: SECURITY

Overview

Security will impact transportation in various ways. Transportation security involves terrorism, piracy, organized crime, illegal drug manufacturing and trafficking, cyber crime, and smuggling. The importance of transportation security continues to increase with globalization, regional integration, and increasing connections between communications and transportation technologies.[17]

Key Drivers

The drivers for security are described in table 4.7.

Table 4.7. Key Drivers of Security.

Key Driver	Description
Travel demand and supply	• Increase in travel demand leads to expansion of the current transportation network system • Expansion of current transportation network system will bring new security challenges to the transportation agencies as interdependencies between existing transportation modes become more complex
Technology development	• Development of intelligent transportation systems (ITS) and improved surveillance technologies allows for real-time traffic management and faster decision making • Increase in technology allows for accurate and reliable security measures
Funding	• Funding provides the necessary capital for investing in sophisticated surveillance technology, and law enforcement and worker security training
Globalization	• Rise in international travel and globalization permits terrorists greater opportunities to enter the United States • Increase in international traffic lends itself to heightened security measures as terrorists and criminals become smarter

Six Worlds

Table 4.8 shows how key drivers impact the future of security as they move from the most negative world (Crisis) to the most positive world (Green).

Table 4.8. Key Drivers and Their Impacts on the Future of Security in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Travel demand and supply	No, people focus more on basic needs, with no demand for travel and no security measures in place	Slight increase but no significant movement of people, leading to no advanced security measures in place	More increase in intercity travel demand, leading to heightened security awareness	Decrease in travel demand and stronger cyber security measures due to technological advancement	Increase in travel demand and strong cyber security measures and larger law enforcement	Increase in travel demand and strong cyber security measures and larger law enforcement
Technology development	No, lack of resources leads to no investment for technology to enhance transportation security	Increase in funding gradually allows for exploring new technology to enhance transportation security	Increase in development of new and sophisticated surveillance and security technology	Active development and implementation of new and sophisticated surveillance and security technology	Active development and implementation of technology strengthens border security and restricts cyber attacks	Active development and implementation of technology eliminates terrorist attacks
Funding	No, lack of funding leads to no investment in technology or law enforcement	Slight increase in funding allows investment in new technology and training law enforcement	More increase in funding allows better security measures	More increase in funding allows better security measures	Adequate funding allows implementing all of the necessary security measures	Substantial amount of funding allows implementing various security measures
Globalization	No, poor economic conditions lead to no international traffic and rare attacks	Slight increase in international traffic leads to several attacks	Greater increase international traffic leads to frequent attacks and heightened security awareness	Increase in international traffic and frequent attacks lead to development of new security measures	Significant increase in international traffic, but technology reduces attacks	Significant increase in international traffic, but technology eliminates attacks

TECHNICAL AREA: NATURAL-RESOURCE AVAILABILITY

Overview

Natural resources will impact transportation in various ways. The availability and price of natural resources, including many forms of energy, will significantly affect the United States' ability to provide highway transportation in the future. The construction, rehabilitation, and maintenance of America's highways are all dependent upon the availability of energy and other natural resources at an affordable price. Some of the required resources include petroleum, metals, ceramics, precious metals, trace elements, and other materials. If these natural resources are not available at an affordable price, significant changes will be required.

Key Drivers

The drivers for natural resources are described in table 4.9.

Table 4.9. Key Drivers of Natural-Resource Availability.

Key Driver	Description
Geopolitical conditions	• The availability and price of energy and some raw materials are dependent upon world geopolitics • Petroleum is especially vulnerable • Some precious metals and trace elements are vulnerable
Primary energy sources	• Primary energy sources in the world and the United States include petroleum or crude oil, coal and sub-bituminous coal, nuclear, hydro-electric, and natural gas • Liquids (liquefied petroleum gas, compressed natural gas, and liquefied natural gas), bio-fuels, and renewable sources are becoming important
Alternative sources of crude oil and crude-oil substitutes	• Alternative sources of crude oil (like Canadian tar sands and shale oils) will continue to develop in the future
Transportation vehicle energy sources	• Transportation uses a large amount of energy; the development of new sources of energy for transportation vehicles will occur in the future
Binders and aggregates	• Graded aggregate, asphalt binders, Portland cement, and lime are the primary materials used for construction, reconstruction, rehabilitation, and maintenance
Other raw materials—metals, precious metals, precious materials, trace elements, and other materials	• Other raw materials include iron ore, aluminum ore, trace elements used in metal manufacture, and other elements used for digital electronic equipment • Steel for reinforcement in structures and pavements and structural steel for bridges

Six Worlds

Table 4.10 shows how key drivers impact the future of natural-resource availability as they move from the most negative world (Crisis) to the most positive world (Green).

Table 4.10. Key Drivers and Their Impacts on the Future of Natural-Resource Availability in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Geopolitical conditions	High impact. Constantly unstable.	Medium impact. Moderately stable.	Medium impact. Mostly stable.	Medium impact. Mostly stable.	Low impact. Stable and uninterrupted.	Low impact. Stable and uninterrupted.
Primary energy sources	High impact. High price and constantly disrupted supply.	High impact. Frequently disrupted supply.	Medium impact. Occasional disruptions.	Medium impact. Occasional disruptions.	Medium impact. Uninterrupted supply.	Medium impact. Uninterrupted supply.
Alternative sources of crude oil and crude-oil substitutes	High impact. Not developed.	High impact. Some progress in developing alternative energy sources.	Medium impact. Progress made in developing alternative energy sources.	Medium impact. Progress made in developing alternative energy sources.	Medium impact. Alternative sources are readily available.	Medium impact. Alternatives and renewable fuel sources are readily available.
Transportation vehicle energy sources	High impact. Underway but underfunded.	High impact. Slow development.	Medium impact. Medium development.	Medium impact. Slow development.	Low impact. Accelerated development.	Low impact. Significant development.
Binders and aggregates	High impact. Available but at a high price.	High impact. Available at a fluctuating price.	Medium impact. Available, but transportation of aggregate is difficult.	Medium impact. High availability.	Medium impact. High availability.	Low impact. Supply is decreased. Alternatives are available.
Other raw materials—metals, precious metals, precious materials, trace elements, and other materials	Medium impact. Limited supply.	Medium impact. Generally available except during political turmoil.	Medium impact. Generally available.	Medium impact. Decreased availability.	Medium impact. Mostly available.	Medium impact. Low availability due to economic pressures.

TECHNICAL AREA: FINANCE AND BUDGET

Overview

Funding and financing issues impact transportation by providing the means for infrastructure development in all areas of the nation and across all modes. The biggest issue facing the long-term funding and financing of national infrastructure is the inadequacy of the existing framework. The fuel tax is a continually weakening proxy for actual use of the roadway system and will lose purchasing power as vehicles become more fuel efficient. This means that there will be less revenue available relative to the demand placed on the infrastructure system. Furthermore, investment decisions are typically driven by political motives and arcane formulas, meaning that allocations are not made based on actual need or demand.

Reduced funding means that not only will new development not occur, but needed maintenance and preservation activities will be reduced. Long-term funding and financing issues will have to be addressed to ensure that infrastructure adequately serves the needs of drivers and promotes a healthy economy.

Key Drivers

The drivers for finance and budget are described in table 4.11.

Table 4.11. Key Drivers of Finance and Budget.

Key Driver	Description
Level of domestic spending	• State and federal expenditures on transportation infrastructure, which average about 1.95 percent of GDP, influence the latitude that state and local entities have in addressing infrastructure development through their own means under their own policies
Adoption of new vehicular technologies	• The use of road-use metering technologies influences the availability of empirical data for use in allocating funding resources
National energy policy	• Drives the development of more fuel-efficient vehicles, undermining traditional funding sources such as the fuel tax
National financing structure	• A stronger reliance on user fees will result in more targeted and strategic investment decisions, while private-sector reliance will reduce the ability of state and federal entities to influence transportation infrastructure development

Six Worlds

Table 4.12 shows how key drivers impact the future of finance and budget as they move from the most negative world (Crisis) to the most positive world (Green).

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Level of domestic spending	Economic conditions result in severely reduced levels of investment in transportation infrastructure	Economic conditions result in levels of investment in transportation infrastructure that are average	Overall levels of investment in transportation infrastructure are, historically, average	Overall levels of investment in transportation infrastructure are, historically, average	Overall levels of investment in transportation infrastructure are, historically, average	Overall levels of investment in transportation infrastructure are, historically, average
Adoption of new vehicular technologies	Economic and social conditions slow technology development and adoption	Economic and social conditions slow technology development and adoption	Moderate technology innovation and adoption due to stable economic conditions	Moderate technology innovation and adoption due to stable economic conditions	Rapid technology development and market penetration	Rapid technology development and market penetration
National energy policy	Very high fuel prices but continuing reliance on fossil fuels	High fuel prices but continuing reliance on fossil fuels due to a lack of technology development	Technology development and moderate fuel prices lessen dependency on fossil fuels	Moderate fuel prices and significant shift to alternative fuels	Alternative fuel sources develop rapidly, reducing reliance on fossil fuels	Reduced reliance on fossil fuels due to rapid development of alternative fuel sources
National financing structure	No imposition of user fees due to public opposition and little reliance on private investment	No imposition of user fees due to public opposition and low reliance on private infrastructure provision	Significant privatization, reliance on user fees weakens federal and state influence	Significant privatization, reliance on user fees weakens federal and state influence	Strong federal regulation precludes significant privatization and wide-scale reliance on user fees	Strong federal regulation precludes significant privatization and wide-scale reliance on user fees

Table 4.12. Key Drivers and Their Impacts on the Future of Finance and Budget in the Six Worlds.

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TECHNICAL AREA: HUMAN RESOURCES

Overview

The future performance of the transportation system will depend on the quality and quantity of the human resources that design, build, operate, and maintain the various components of that system. The quality and quantity are affected by a number of drivers, the foremost being an appropriate education at all levels—from the roadway maintenance worker to the leadership at corporate and DOT offices.

The transportation sector has historically suffered from an image problem because employment rewards and compensation are not as enticing as those of many competing industries. The performance of the transportation system thus becomes dependent on the quality of the education of the workforce that eventually seeks it as a destination in the transportation sector. Opportunities outside the sector can be a great detractor in getting an appropriately educated workforce, and in whether its supply is in equilibrium with the demand.

Key Drivers

The drivers for human resources are described in table 4.13.

Table 4.13. Key Drivers of Human Resources.

Key Driver	Description
Skills required	• Mechanization of future maintenance and construction tasks will demand on a more qualified and skilled workforce in general • Robotics can be used to replace some low-level labor; adoption within the sector will depend on unions (if applicable for a given geographical region)
University education	• Transportation-sector leaders will be, of necessity, graduates with advanced degrees • The quality of future leadership will depend on competing job opportunities in other sectors of business and commerce
Technical education	• For middle management, a highly technical education coupled with relevant experience will be a workplace requirement • Many future tasks will be shifted to robotics and other advanced mechanization techniques; this will require highly skilled technical workers for leading controlling and planning operations
Trade education	• The journeymen of yesteryear will have much higher performance expectations placed on them within the specialized trades that will exist in the future transportation sector • Mechanization of the most basic of tasks can be expected; skilled (trade-based) types of workers will be in demand in lieu of an unskilled/untrained labor pool
Transportation skills capacity	• The transportation sector often suffers from a poor image, and at best is only moderately well paid • The supply and demand of an appropriately educated and focused workforce will depend on other competing opportunities in other industries (such as manufacturing and the service sector) and whether there is a perception that transportation has good long-term sustainable prospects

Six Worlds

Table 4.14 shows how key drivers impact the future of human resources as they move from the most negative world (Crisis) to the most positive world (Green).

Table 4.14. Key Drivers of Human Resources and Their Impact in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Skills required	Sufficient labor, but mostly unskilled.	Sufficient labor, but unskilled and restricted to historic methods of mechanization.	Increasing demand for mechanization of most tasks.	Increasing demand for mechanization of most tasks.	High demand for robotic mechanization requiring a highly skilled workforce.	High demand for robotic mechanization requiring a highly skilled workforce.
University education	Due to poor salaries, engineering students go to other industries. Few go to college	Due to poor salaries, engineering students go to other industries.	Sufficient graduates, but few remain long-term in transportation.	Sufficient graduates, but few remain long-term in transportation.	Great job opportunities in engineering with scholarship funding.	Good opportunities, but a stigma working for the green industries.
Technical education	Basically nonexistent.	Basically nonexistent. Most go into manufacturing.	Sufficient training, but lured away to more attractive opportunities.	Sufficient training, but lured away to more attractive opportunities.	Opportunities for super-technicians to deal with the new generation of robotic machines.	Good opportunities to deal with the new generation of robotic machines.
Trade education	Classic tradespersons abound, but language acts as an employment barrier.	Classic tradespersons abound, but language acts as an employment barrier.	Skilled workers exist, but have competing and more attractive opportunities.	Skilled workers exist, but have competing and more attractive opportunities in private-sector manufacturing.	Well-paid jobs for the technicians of yesteryear.	Stigma from the non-green past lingers, and not a preferred destination.
Transportation skills capacity	Demand far outstrips supply in all sectors.	Demand outstrips supply, but sufficient labor exists for maintenance.	In equilibrium, but a revolving door problem exists because transportation is not a glamour sector.	In equilibrium, but a revolving door problem exists because transportation is not a glamour sector.	High demand for specialized skills and met by eager workforce.	Demand for specialized skills met by a green workforce, but workers are unsettled, and the sector is unstable.

TECHNICAL AREA: COORDINATION

Overview

The development and maintenance of a highway transportation system is dependent upon a number of partnerships among the state transportation agencies, other public agencies, and private industries. Coordination of these various entities is crucial to both the short-term and long-term success of a transportation system.

As the world changes, so do the demands on our transportation systems. Intermodal facilities to handle passenger and freight movement will become more important in the future. Related government agencies and industries will supply an increasing amount of technology that highways will adopt. Policy and regulatory agencies will play an increasingly important role in the design, delivery, and maintenance of highway transportation facilities.

Key Drivers

The drivers for coordination are described in table 4.15.

Table 4.15. Key Drivers of Coordination.

Key Driver	Description
Intermodal considerations	• Intermodal considerations include the transfer of passengers and freight between highways, water, rail, air, pedestrian, bicycle, and transit • The construction of new intermodal facilities in the future and the planning for the impacts on the modes of transportation involved in the facility need coordination and partnerships to be formed among the various agencies involved in the facilities
Related industries	• A large number of industries are vital to the development and maintenance of our transportation system, including industries responsible for freight movement, advanced transportation technologies, basic and applied sciences and engineering, engineering consultants, materials suppliers, and contractors
Policy and regulatory agencies	• The coordination among all of the parties responsible for environmental policy and regulation is crucial to project success • Coordination with FHWA, fair trade and labor organizations, utility companies, railroad owners, and right-of-way purchases is vital as well

Six Worlds

Table 4.16 shows how key drivers impact the future of coordination as they move from the most negative world (Crisis), to the most positive world (Green).

Table 4.16. Key Drivers and Their Impacts on the Future of Coordination in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Intermodal considerations	Medium impact. Slowly adopted due to funding constraints.	Medium impact. Slowly adopted due to funding constraints.	Medium-high impact. Facilities are developed thanks to a stronger economy.	Medium-high impact. Slow development due to dispersed population development.	High impact. Intermodal facilities are rapidly developing.	High impact. Intermodal facilities are rapidly developing.
Related industries	Low impact. Low participation due to economic struggles and risk.	Low impact. Low participation due to economic struggles.	Medium impact. Related industries are more willing to cooperate.	Medium impact. Increased cooperation, and industries are willing to take on risk.	High impact. Increased cooperation, and industries are frequently taking on risk.	High impact. Coordination with related industries is not problematic.
Policy and regulatory agencies	Low impact. Policies are alternatively relaxed and strict.	Low impact. Policy development is steady due to climate change and financial constraints.	Medium impact. Policy development is steady, and environmental changes are noticeable.	Medium-high impact. Policy development is steady, and environmental changes are noticeable.	Medium-high impact. Policy development is steady, and environmental changes are noticeable.	High impact. New environmental policies clearly affect business and transportation agencies.

TECHNICAL AREA: REGULATIONS AND POLICIES

Overview

Transportation policy influences overall transportation infrastructure development because it determines where funding resources are allocated and how those funding decisions are made. This in turn can affect development patterns and the economy, which in turn influence the demand for infrastructure.

The federal government exerts influence in a number of different ways but primarily through funding. States are responsible for allocating revenues received from federal grants (pursuant to the various restrictions placed on the use of those funds) and the allocation of funding from their own revenue sources.

Quasi-governmental entities include toll and mobility authorities and other related entities, such as transit entities, that operate infrastructure assets as a private enterprise but are still subordinate in some form to elected officials. Their influence in transportation policy is continually increasing as pressures on federal and state transportation budgets increase opportunities for tolling and pricing.

Key Drivers

The drivers for transportation regulations and policies are described in table 4.17.

Table 4.17. Key Drivers of Regulations and Policies.

Key Driver	Description
Level of domestic spending on transportation	• State and federal expenditures on transportation infrastructure influence the latitude that state and local entities have in addressing infrastructure development through their own means under their own policies
Planning processes	• Refers to whether infrastructure planning processes are predominately local driven or state and federally driven • Federal and state initiatives related to sustainability and livability reduce local control over planning processes
Reliance on user fees	• A reliance on user fees influences the demand by road users that revenues be allocated to address needs on local transportation infrastructure as opposed to infrastructure identified as state and national priorities
Private-sector infrastructure provision	• The level of investment and level of participation in the provision of transportation infrastructure influence the means by which federal and state entities exert control over infrastructure development (funding and finance versus regulation)

Six Worlds

Table 4.18 shows how key drivers impact the future of regulations and policies as they move from the most negative world (Crisis) to the most positive world (Green).

Table 4.18. Key Drivers and Their Impacts on the Future of Regulations and Policies in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Level of domestic spending on transportation	Economic conditions result in severely reduced levels of investment in transportation infrastructure.	Economic conditions result in levels of investment in transportation infrastructure that are average.	Overall levels of investment in transportation infrastructure are, historically, average.	Overall levels of investment in transportation infrastructure are, historically, average.	Overall levels of investment in transportation infrastructure are, historically, average.	Overall levels of investment in transportation infrastructure are, historically, average.
Planning processes	Economic and social crises result in a focusing of planning authority within local entities.	Economic and social conditions focus planning authority within local entities.	Planning processes are localized due to funding levels.	Planning processes are localized due to funding levels.	Planning processes are dominated by federal prerogatives.	Planning processes are dominated by federal prerogatives.
Reliance on user fees	Economic and social conditions result in strong public opposition to road user fees.	Economic and social conditions result in strong public opposition to road user fees.	Economic conditions facilitate support for the limited use of road user fees.	Economic conditions facilitate support for the limited use of road user fees.	Technology developments support wide-scale user fee deployment.	Technology developments support wide-scale user fee deployment.
Private-sector infrastructure provision	Low public investment leads to a slightly increased private-sector role but on very few facilities.	Low public investment leads to increased private-sector role with a focus on profitable (highly traveled) facilities and areas.	Enhanced role for the private sector in traditionally public ventures.	Slightly enhanced private-sector role in traditionally public ventures. Dispersed nature of the population reduces potential profitability.	Revenues from road user fee deployment reduce the need for private capital in infrastructure development.	Revenues from road user fee deployment reduce the need for private capital in infrastructure development.

TECHNICAL AREA: DEMOGRAPHICS

Overview

Understanding demographic changes is important to identifying future travel patterns and the corresponding demand on the system. “Demographics” is defined as measures of population size and basic dimensions of the population (age, gender, and race), and changes in these measures over time and space. “Socio-demographics” is a broader area that also includes socio-economic aspects such as household size, income, and employment status, which also can affect travel characteristics.

From the perspective of assessing the future demand on the transportation system, spatial aspects that include a geographic dimension are additionally important. For instance, broad demographic measures will help describe interstate and intrastate travel demand, but the geographic dimension is needed to examine regional demand characteristics, including differences in urban and non-urban travel patterns.

Key Drivers

The drivers for demographics are described in table 4.19.

Table 4.19. Key Drivers of Demographics.

Key Driver	Description
Population growth in relation to urban form	• Population growth in densely developed areas will create greater concentrations of highway demand • Population growth in more dispersed urban forms will create lower concentrations of travel demand
Rate of acculturation of foreign-born populations	• Foreign-born Hispanics exhibit differences in trip-making characteristics compared to U.S.-born Hispanics or non-Hispanics, such as lower vehicle ownership, higher transit use, fewer auto trips, and higher carpooling and walking • As the rate of assimilation of immigrant households increases, there will be more auto trips and fewer alternative-mode trips • Assimilation of immigrant populations coupled with improvement in economic conditions leads to increased auto ownership and greater highway use
Changes in household size and dependency ratios	• Household size will increase due to a number of factors, including aging parents residing with adult children, young adults living with parents, and higher fertility rates among immigrants • Households with children make significantly more trips than those without children • The impact of traffic demand at the facility level is highly dependent upon the demographic characteristics (such as household size) within individual regions
Effects of ubiquitous connectivity	• Generational use of information and communication technologies (ICT) can indicate future use of the transportation system • The effects of ICT on travel are unknown; ICT may facilitate the generation of more trips, or as younger generations age, it may lead to more telecommuting and trip reduction

Six Worlds

Table 4.20 shows how key drivers impact the future of demographics as they move from the most negative world (Crisis) to the most positive world (Green).

TECHNICAL AREA: CUSTOMER NEEDS AND EXPECTATIONS

Overview

The term *customer expectation* encompasses many dimensions. A person's expectations are based on their perception of the service being provided, the provider (usually a particular company), and the industry in general. The expectation is formed through the past experience of the person and others the person interacts with. In some instances, it may serve as a proxy for customer satisfaction.

If a service provider, be it a transportation system, a utility provider, or the local grocery store, feels it is meeting customer expectations, it may infer that the customers or system users are also satisfied, but that is not always the case. Other organizations have been more proactive in managing customer expectations and relating that to superior customer satisfaction. This has not typically been the case in the transportation sector, but it has been evolving over time.

Key Drivers

The drivers for customer needs and expectations are described in table 4.21.

Table 4.20. Key Drivers of Demographic Influences and Their Impact on Travel Demand in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Population growth in relation to urban form	Low impact. Population growth is low and more centrally distributed.	Low to medium impact. Population growth is low and more centrally distributed.	Medium impact. Concentrated population, which supports alternative modes.	Medium to high impact as greater dispersion of population leads to more auto trips.	High impact as greater dispersion of population leads to more auto trips.	Medium impact. Concentrated population by regulation, which supports alternative modes.
Rate of acculturation of foreign-born populations	Low impact. Acculturation is slow due to economic conditions, resulting in fewer auto trips and lower auto ownership.	Low impact. Acculturation is slow due to economic conditions, resulting in fewer auto trips and lower auto ownership.	Medium impact. Acculturation is at a moderate pace, resulting in more auto trips and higher vehicle ownership.	Medium impact. Acculturation occurring moderately, resulting in more auto trips and higher vehicle ownership.	High impact. Acculturation increasing, resulting in more auto trips and higher vehicle ownership.	Medium impact. Acculturation increasing. More trip making and higher vehicle ownership, but demand regulated.
Changes in household size and dependency ratios	Low to medium impact, with higher household sizes and more per-household trip making.	Low to medium impact, with higher household sizes and more per-household trip making.	Medium impact. Slightly smaller households but more of them. Higher overall trip making with some by transit.	Medium to high impact. Slightly smaller households but more of them. Higher overall trip making.	High impact. Smaller households but more of them. Higher overall trip making.	High impact. Smaller households but more of them. Higher overall trip making.
Effects of ubiquitous connectivity	Medium impact. Lower technology adoption will fail to appreciably reduce demand.	Medium impact. Lower technology adoption will fail to appreciably reduce demand.	Medium impact. Moderate technology adoption makes inroads in reducing demand.	Technology adoption has the effect of lowering demand on the system.	High technology adoption has the effect of lowering demand on the system.	High technology adoption has the effect of lowering demand on the system.

Table 4.21. Key Drivers of Customer Needs and Expectations.

Key Driver	Description
Acceptance of private-sector involvement	• Concern that facilities will be undervalued • Concern that upfront payments by concessionaires will not be used for transportation • Concern about the length of concession agreements • Concern over non-complete clauses • Limited opportunities for public participation • Concern about maximizing revenues over maximizing facility use • Cherry-picking of profitable projects • Windfall revenues for the private sector • Fear of private sector having powers of eminent domain • Concern that other system needs will go unmet
Acceptance of user fees	• Current limited experience and acceptance • Will vary depending on circumstance • Acceptance may increase with deteriorating conditions
Globalization	• Increased awareness of global issues shapes expectations • Public opinion about free trade, globalization, and international relations will affect expectations • Greater customer awareness of where products are produced may influence freight transportation • The greater the availability of traveler information, the greater the expectation
Movement toward sustainability	• May affect freight transportation, especially internationally • May be affected by technological advances • To the extent that transportation and consumerism are linked and have causal effects on each other, transportation will be impacted by changing attitudes and practices regarding consumerism, thus affecting expectations

Six Worlds

Table 4.22 shows how key drivers impact the future of customer needs and expectations as they move from the most negative world (Crisis) to the most positive world (Green).

Table 4.22. Key Drivers and Their Impacts on the Future of Customer Needs and Expectations in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Acceptance of private-sector involvement	No, in times of crisis, expectation that governments will step in to provide basic services.	Public concern over this.	More acceptance and higher expectation.	Greater level of services increases acceptance.	Plays a large role through technology or asset management.	Mostly accepting but involvement is more limited.
Acceptance of user fees	Private sector will take over profitable assets, and public will have little choice.	Little acceptance but higher expectation of private facilities.	Governmental controls could increase acceptance.	Fees will be assessed locally and be market driven, increasing acceptance.	Changes in project delivery will have acclimated the public to become more accepting.	Changes in project delivery will have acclimated the public to become more accepting.
Globalization	Little interest in globalization as country struggles.	No heightened sense of effects of globalization.	Greater awareness of the effects of globalization on the transportation system but strong need for global commerce.	High expectations. Enhanced through technology.	High expectations. Enhanced through technology.	Little public expectation.
Movement toward sustainability	Involuntary movement due to decreased resources.	Gradual movement; not regulated.	Movement becomes more regulated.	Smaller communities voluntarily move toward sustainability.	Becomes more regulated.	Highly regulated.

TECHNICAL AREA: TRAFFIC

Overview

Traffic loading on the highway system will be examined from perspectives of capacity, mode, and flow characteristics. “Loading” can be described as traffic demand in relation to capacity. Both demand and capacity are specific to individual highways, although there are common attributes within categories of urban highways, suburban highways, and rural highways.

There is a temporal aspect to traffic loading of highways in metropolitan regions that experience high levels of congestion during peak hours and minimal congestion during off-peak periods. Sizing the infrastructure for peak conditions is inefficient and infeasible, but actions to significantly ration and redistribute demand through trip reduction or pricing have met with resistance.

In addition to background demand, the way the highway infrastructure carries that demand can influence capacity requirements. “Traffic flow” describes the movement of individual vehicles and their interactions with the highway and with each other. As vehicle design and associated in-vehicle and roadside technology develop over time, the ability to influence flow, density, speed, and headway without increasing the footprint of the existing infrastructure, or by minimizing its expansion, can result in greater loading of the system than currently allowed under existing standards.

Key Drivers

The drivers for traffic are described in table 4.23.

Table 4.23. Key Drivers of Traffic.

Key Driver	Description
Highway demand in relation to capacity	• Urban highways in dense urban areas commonly have greater demand than available capacity allows, while rural highways that serve a connectivity function typically have less demand than the available capacity would allow • There are three possible traffic loading perspectives for the highway system: demand is increasing relative to capacity, stable, or managed through technology and pricing, particularly with respect to equalizing demand with capacity during the most congested periods
Transit alternatives	• Demand for bus and rail transit and other non-motorized modes may respond to two factors: the investment in infrastructure to make transit and alternative passenger modes more accessible or more attractive; and the demand for (or shift of mode to) transit because of individual lack of alternatives due to economics, geography, trip characteristics, etc.
Freight alternatives	• Demand on the highway system can be influenced by new or alternative freight systems, such as a shift to rail or development of new delivery systems, such as a freight shuttle • Continuation of the trend toward greater non-store retail purchasing will drive freight supply and demand away from long-haul carriers and toward air carriers coupled with less-than-truck load or smaller-class truck freight shipments • Increases in foreign trade will lead to growth into maritime and inland port traffic, and the expansion in containership traffic will exacerbate the need for landside connectivity of ports to points of transfer and delivery
Vehicle type, characteristics, and technology	• Traffic flow is more consistent and uniform when variations in vehicle type and vehicle characteristics are minimized • Leading-edge vehicle technologies have the potential to reduce vehicle headway, which influences the demand-carrying capacity of a highway • Technological improvements in vehicle equipment related to acceleration and braking that are designed for safety can potentially smooth flow by creating a more operationally homogenous vehicle mix

Six Worlds

Table 4.24 shows how key drivers impact the future of traffic as they move from the most negative world (Crisis) to the most positive world (Green).

Table 4.24. Key Drivers of Traffic and Their Impact in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Highway demand in relation to capacity	Demand in relation to capacity is largely stable.	Demand related to capacity is increasing. Capacity is constrained due to funding limitations.	Demand high, but greater stability with the emergence of private-sector involvement in capacity growth.	Demand in relation to capacity becomes more stable as traffic loading is likewise dispersed.	Technology and greater user acceptance result in managed demand through pricing.	Technology and greater user acceptance result in managed demand through pricing.
Transit alternatives	Focus on urban mega-regions results in emergence of transit for short trips, though resources are limited for transit capacity growth.	Focus on urban mega-regions results in the emergence of transit for short trips, though resources are limited for transit capacity growth.	Transit emerges as a strong component of the system since the concentrated mega-region offers viable service.	Transit alternatives have lower opportunity for success because of dispersed residential and employment locations.	Transit becomes a less important component due to technology's ability to manage roadway capacity for loading and shift peak demand.	Sustainability interests drive transit investment.
Freight alternatives	Limited freight alternatives due to funding constraints.	Limited freight alternatives due to funding constraints.	Economic stability allows alternatives to emerge.	Economic stability allows alternatives to emerge.	Growth in freight alternatives as consumers place a greater reliance on e-commerce.	Sustainability interests drive freight investments.
Vehicle type, characteristics, and technology	Wide variations in vehicle operating characteristics and minimal technology advancement.	Wide variations in vehicle operating characteristics and minimal technology advancement.	Advanced vehicle technologies support demand management.	More homogenous mix of vehicle characteristics as freight alternatives emerge.	More homogenous mix of vehicle characteristics with technology, allowing more efficient loading.	Sustainability drives choices by travelers, facilitated by vehicle technology and efficient loading.

TECHNICAL AREA: SAFETY

Overview

Transportation safety addresses safety ratings, degradation, risk assessment, and structural integrity of transportation infrastructure. The activities or incidences that affect transportation safety are natural disasters, weather, degradation of infrastructure, and accidents. Highway transportation safety concerns include protecting the drivers/operators/passengers and also construction workers in work zone areas. The difficulty of managing safety in highway transportation is dealing with the continuous flow of high-speed vehicles in relatively tightly managed space.

Key Drivers

The drivers for developing and implementing safety are described in table 4.25.

Table 4.25. Key Drivers of Safety.

Key Driver	Description
Funding	• Lack of funding can delay maintenance work and adding protective measures such as cable barriers, guardrails, medians, and tone bands to prevent accidents • Funding will provide the capital necessary for training, establishing current technical standards, and improving management routines in order to establish a safe work environment
Public demand for safety	• Public demand will have a large effect on how government responds to monitoring the current serviceability of the highway infrastructure • As public demand grows, the government may find that people are more accepting of disruption to the flow of traffic even at some inconvenience to them
Technology	• Technological improvements (connected vehicle technology, real-time data capture, etc.) bring new and innovative ways to reduce accidents • Automotive technology (dashboards with smart phone/iPod docks, TV/DVD players in vehicles, etc.) can also lead to deadly distraction while driving
Government regulation	• Government enforcement will increase as people demand better safety measures and as the number of traffic-related accidents increases • Regarding safety, the government may enforce stringent preplanning and traffic safety management and even enforce real-time monitoring of traffic

Six Worlds

Table 4.26 shows how key drivers impact the future of safety as they move from the most negative world (Crisis) to the most positive world (Green).

INTEGRATION OF TECHNICAL AREAS

This last section identifies a set of key drivers and their relationships based on all 13 technical areas. Researchers used the systems dynamic methodology to make this assessment, and created a causal loop diagram to represent the relationships.

A systems diagram is a tool to understand the dynamics of complex systems. Use of the systems dynamic approach has been proposed in one of the other studies, 20-83(6), to draw relationships and understand the effect of socio-demographics on travel demand. It is useful in showing how a change in one factor may impact another. A systems diagram is represented by feedback loops that are either positive (self-reinforcing, denoted as R in this study) or negative (self-correcting, denoted as B in this study). Positive loops tend to amplify whatever is happening in the system, and negative loops neutralize the change.

A systems diagram is a simplified version of an individual's mental model. It does not include every variable that can affect a change to the system. Rather, the modeler purposely draws a boundary to understand the focusing question that he or she is trying to answer and limits the number of key variables in the model.

Figure 4.2 shows a systems diagram that was developed based on the assessment of the 13 technical areas. This diagram was developed with the help of the project's futurist in preparation for the workshop (see chapter 5) to facilitate a deeper understanding of the areas of interest and to start consolidating the key drivers and their uncertainties in formulating multi-driver scenarios (see chapter 6).

Table 4.26. Key Drivers and Their Impacts on the Future of Safety in the Six Worlds.

Driver	Crisis World	Dirty World	Mega World	Suburban World	Wonder World	Green World
Funding	No, funding is diverted to provide basic services.	Small amount of funding is available to maintain the minimum safety level.	More funding is available for safety investment.	Fair amount of funding is available for safety investment.	Adequate funding is available for adopting advanced safety measures and devices.	Unlimited amount of funding is available for enterprise-based safety monitoring across the United States.
Public demand for safety	No, public concerns are diverted to meeting basic needs.	Demand will increase as number of accidents rises.	More demand from public for sophisticated and reliable safety measures.	Gradual decrease as technology prevents many accidents.	Further decrease as technology will prevent most accidents.	Little demand as technology aids in eliminating accidents.
Technology	No, lack of funding hampers investing in technology to improve transportation safety.	No new technology and only a few adopted. Justifying the cost of implementation is difficult.	Active development but difficulty in adopting safety technology.	Active development and adoption of sophisticated safety technology.	Slower development and adoption due to sharp decrease in number of accidents.	Even slower development and adoption due to government restrictions.
Government regulation	No, transportation safety is not a national priority.	Gradual movement, government encourages private-sector partnership.	More regulated, governmental control increases to maintain public safety.	More regulated, governmental control increases to maintain public safety.	Governmental control decreases to encourage private-sector involvement.	Highly regulated to protect the public.

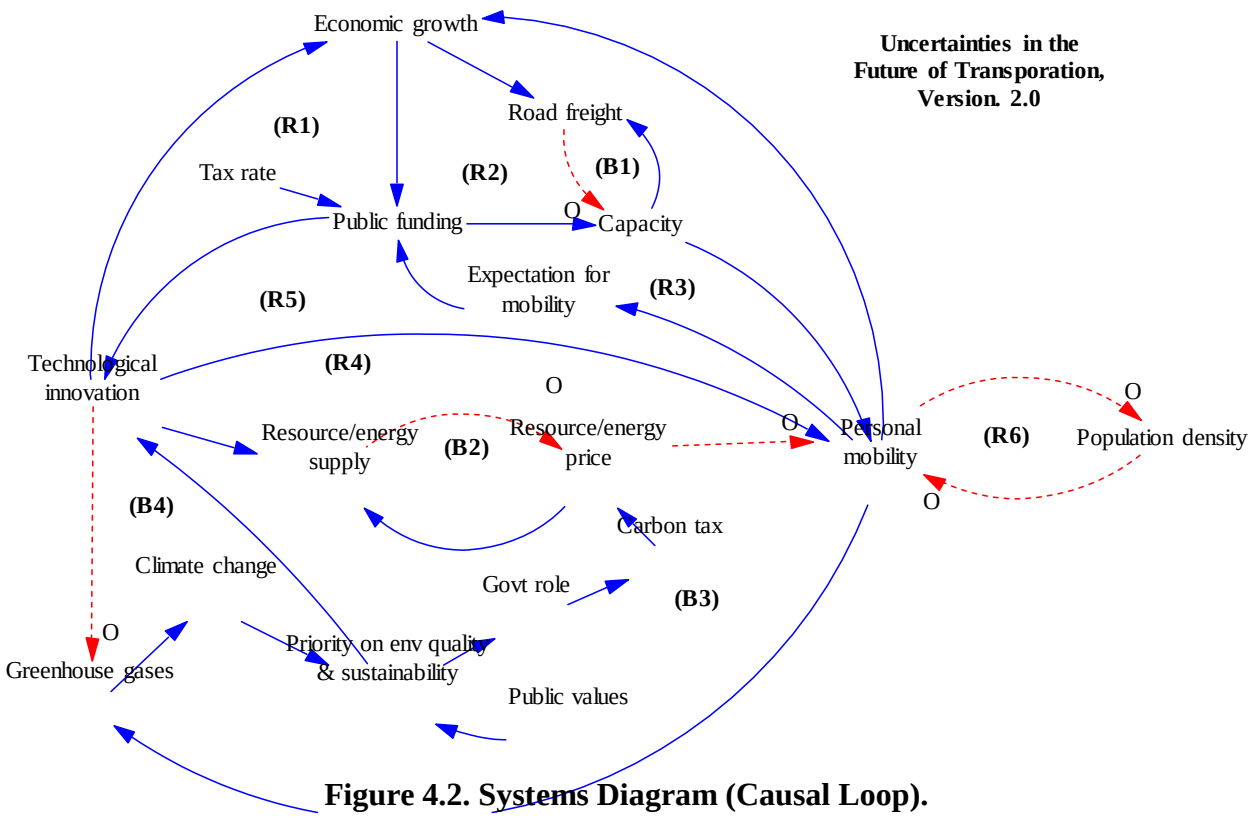

Figure 4.2. Systems Diagram (Causal Loop).

Figure 4.2 is a simplified mental picture of all of the worlds described for the 13 technical areas, showing positive/self-reinforcing loops (R) and negative/self-correcting loops (B). "O" denotes an opposite relationship, also shown by a red dashed line; an opposite relationship occurs when the increase in one variable causes the decrease in another variable. The diagram includes the following loops:

- **Loop R1:** The more technology, the more economic growth, the more public funding, the more technology. Technology fuels economic growth, which provides the necessary funding for additional investment in technology.
- **Loop R2:** The more economic growth, the more public funding, the more road capacity, the more personal mobility, the more economic growth. More funding allows for more personal mobility, which further intensifies economic growth.
- **Loop R3:** The more public funding, the more road capacity, the more personal mobility, the more expectation for mobility, the more public funding. As the expectations for mobility continue to increase, the public is more inclined to invest in highway infrastructures.
- **Loop R4:** The more technology, the more personal mobility, the more economic growth, the more technology. In the long run, advancement in technology allows economic growth.
- **Loop R5:** The more technology, the more personal mobility, the more expectation for mobility, the more public funding, the more technology. In the long run, advancement in technology allows public funds to be available for additional technological innovations.

- **Loop R6:** The more personal mobility, the less population density, the more personal mobility. Personal mobility is affected by population density and fuel price. More suburbanization leads to more personal mobility.
- **Loop B1:** The more road freight, the less road capacity (due to deterioration), the less road freight. Economic growth leads to more freight movement, but this in turn leads to less capacity and reduction of freight movement.
- **Loop B2:** The more energy supply, the less energy price, the less energy supply. The fuel price fluctuates according to supply and demand.
- **Loop B3:** The more personal mobility, the more greenhouse gases, the more climate change, the more priority on environmental quality and sustainability, the more government role, the more carbon tax, the more energy price, the less personal mobility. The high cost of fuel brings down demand for personal mobility.
- **Loop B4:** The more technology, the less greenhouse gases, the less climate change, the less priority on environmental quality and sustainability, the less technology. The need for sustainable growth and environmental concerns encourages more technological innovations.

SUMMARY

This chapter describes 13 technical areas, key drivers in those technical areas, and six possible worlds for each technical area. The worlds form the **background, or the database of information,** that helped researchers develop a final set of drivers (see chapter 5) and multi-driver scenarios (see chapter 6). The research team has spent considerable effort researching and assessing how drivers in each of the 13 technical areas will impact the future 30 to 50 years from now. Approximately 67 drivers were identified, and 78 worlds were developed over the 13 technical areas based on the 20-83(07) framework of six worlds.

CHAPTER 5: SCENARIO PLANNING WORKSHOP

Chapters 2 through 4 (Tasks 1 through 3) provided the background information needed to create multi-driver scenarios required to accomplish the Phase I objective. To accomplish Task 4: Scenario Development, the research team determined that conducting a one-day workshop facilitated by the team's futurist would be the best approach to define a set of final drivers that will influence the future of transportation.

This chapter discusses holding the workshop and identifying key drivers, while chapter 6 discusses the work accomplished on the scenarios as a result of the workshop.

This chapter focuses on the following steps:

- **Step 9: Hold a Workshop.** The workshop, facilitated by the research team's futurist, included those team members who were involved in creating the drivers and worlds for each of the 13 technical areas. Participants brainstormed the basis for developing multi-driver scenarios.
- **Step 10: Identify Key Drivers.** The output of the workshop resulted in 21 key drivers, representing those drivers that would have the most substantial impact on the future. Also developed in this workshop were characteristics that describe the expected future and alternative futures for each of the 21 key drivers.

Figure 5.1 shows the steps discussed in this chapter.

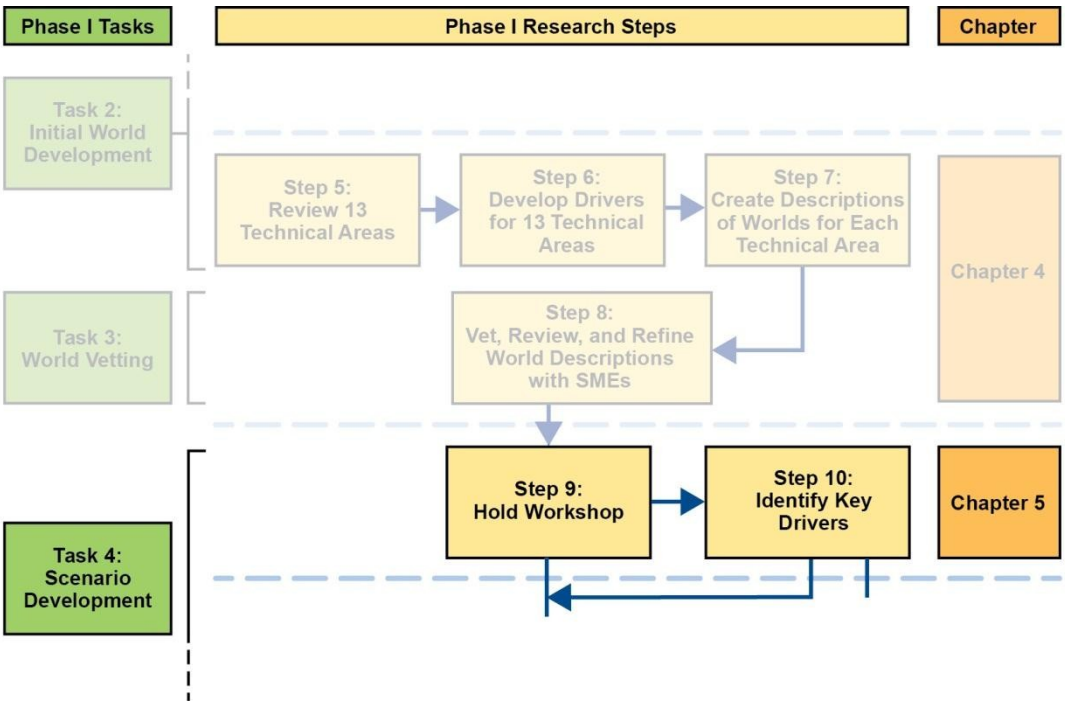

Figure 5.1. Research Process Discussed in Chapter 5.

THE WORKSHOP

The 12 participants in the workshop were the same research team members who analyzed the 13 technical areas described in chapter 4. Thus, they had developed an understanding of the scenario planning methodology and the impact the 13 technical areas have on the future of transportation.

The workshop was held Friday, July 1, 2011, in College Station, Texas. It started with a review of the 20-83(03) project objective and specifically the Phase I objective.

Group discussion identified the workshop objectives as:

- Identifying and defining the major drivers.
- Defining the relationships between those drivers.
- Defining expected and alternative futures of those drivers.
- Defining the underlying assumptions required to form expected and alternative futures.

IDENTIFYING KEY DRIVERS

The group defined major drivers as forces they considered would have a significant effect on the future of highways over the next 30 to 50 years. Participants aimed to identify and understand the commonality and distinctiveness among the 13 technical areas by identifying the major forces. Then, a single representative diagram (the system diagram in figure 4.2) would serve as a communication tool to discover major insights that could be useful for transportation stakeholders in planning future strategies.

To identify the major drivers, the workshop participant combined and listed all of the drivers used in the various world descriptions for the 13 technical areas. The list identified a total of 67 drivers.

Before filtering through the 67 drivers, a general discussion clarified the domain—that is, highway infrastructure, including planning, design, construction, and operations of facilities. Included in the domain were maintenance, preservation, rehabilitation, and reconstruction projects.

The team also needed to understand history as a basis for future prediction. To set a context, the team discussed historical events that led the United States to the current Interstate Era. The team identified different eras in which to understand continuous and discontinuous events, defined as follows:

- **Continuous events** or changes lead to forming the expected future. The common assumption in forming the expected future is that the past trend will continue in the same direction at a similar rate into the future.
- **Discontinuous events**—such as 9/11, revolutions, and technological innovations—are identified to challenge the expected futures and develop alternative futures. Alternative futures contradict the expected future where radical events disrupt past trends.

The major events and the characterization of the interstate and post-interstate eras are described more in detail in appendix D.

With a comprehensive understanding of the domain and context, the team critically reviewed all 67 drivers to determine the magnitude of the impact they had on the highway infrastructure, including planning, design, construction, and operations of facilities in the context of maintenance, preservation, and renewal. This process included eliminating drivers that had minor impact and capturing those drivers that had a large impact on the domain. Through this exercise, the group condensed the list to 21 drivers to be further investigated for building multi-driver scenarios. The number of drivers needed to be limited to what the team decided were the most influential without complicating the effort. The group judged that these drivers have the greatest impact on the domain and are critical to shaping future strategies.

The 21 final drivers are:

1. Climate change.
2. Economic growth.
3. Priority on environmental quality.
4. Funding—amount.
5. Funding—proportion private.
6. Government role—large/small (attitudes toward regulation and tax).
7. Government role—federal/state/local.
8. Mobility—demand (need to work, shop, etc.).
9. Mobility—capacity and access.
10. Mobility—expectations for mobility.
11. Population density.
12. Public commitment to sustainability.
13. Resources/energy—supply.
14. Resources/energy—demand (global).
15. Resources/energy—gas or carbon tax.
16. Resources/energy—price.
17. Road freight (amount and proportion).
18. Security.
19. Technology—physical and fixed.
20. Technology—information technology (IT).
21. Transportation choices/complexity.

After identifying the final drivers, the research team assessed each driver in terms of the expected future trend and rate of change (30 to 50 years from now). They also identified alternatives to the expected future trend and rate of change for each driver. This effort started in the workshop and was completed after the workshop. Members of the research team analyzed one or more drivers and the impact each driver may have on expected and alternative futures.

Table 5.1 lists the 21 drivers, the corresponding expected and alternative futures, and the rationale (assumptions) used to justify them. The expected future—the baseline—focuses on an assessment of the trend and rate for the driver if present trends continue, current plans are fulfilled, and existing projections are correct. Alternative futures are what may happen in lieu of the expected future.

Workshop participants identified possible alternative futures and developed short narratives for them. Then, for each driver, they picked one or two alternative futures that contradict the expected future (shown in table 5.1). The alternative futures included a mix of positive and negative alternatives. This approach helps simplify the descriptions of the alternate futures provided in chapter 6.

Included in the workshop assignment was the development of short narratives of the expected and alternative futures for each major driver. The narratives are documented in chapter 6.

SUMMARY

The July workshop identified the final list of drivers (forces) that will influence the future of highways over the next 30 to 50 years. Each of these drivers is expected to behave in a particular way over that time period. These expectations are described in the baseline or expected future—the most likely future to occur compared to any of the others. The baseline future is not probable in the strict mathematical sense. It is simply more likely than any of the other individual scenarios, but it is not more likely than all the other futures combined. Alternative futures provide a different trend and rate of change over 30 to 50 years.

The research team used the baseline future and alternative futures and the 21 drivers to develop six multi-driver scenarios in the next chapter.

Table 5.1. Workshop Table with Expected and Alternative Futures.

No.	Driver	Expected Changes	Alternative Changes	Rationale for Alternative Changes
1	Climate change	More, moderate	More, high	Economic redirection, negative GHG emission growth Rapid economic growth, intensive reliance on fossil fuels
2	Economic growth	Some, slow	More, fast	Global competition Protectionism U.S. debt Bio/nano-tech industries Higher transportation costs
3	Priority on environmental quality	More, medium	Less, medium	No economic growth Job losses Rising unemployment
4	Funding—amount	Less, fast, per unit	More, slow, total	Better economy Political pressure from commercial transport industry User fees (public acceptance, interstate tolling, technology) Natural disaster Gas tax
5	Funding—proportion private	More, medium	More, medium	Large-scale move to invest in infrastructure, safety, mileage-based user fees Privatization, outsourcing of operations Way to overcome budget deficit
6	Government role—large/small (attitudes toward regulation and tax)	Smaller, slower	More, medium	Move to performance-based allocation
7	Government role—federal/state/local	Less federal, slow	More federal, medium	Funding crisis (states/local entities left to address gaps in funding themselves) Focus and emphasis on local sustainability

No.	Driver	Expected Changes	Alternative Changes	Rationale for Alternative Changes
8	Mobility—demand (need to work, shop, etc.)	More, medium	More, slow	Economic growth with limited alternatives Modal alternatives dampen growth in demand
9	Mobility—capacity and access	More, slow	More, moderate	Funding deficiencies unresolved Alternative funding facilitates expansion
10	Mobility—expectation for mobility	More, slow	Less, slow	Sluggish economy Increasing congestion Funding
11	Population density	More, slow	Less, medium	Trends toward growth point to cities, decline in rural population Technology may allow people to live where they want, attitudes toward sustainability may drive it
12	Public commitment to sustainability	More, slow	Less, slow	Economic stagnation Environmental disasters
13	Resources/energy—supply	More, slow	More, very slowly More, medium	Supply restrictions Supply expansions
14	Resources/energy—demand (global)	More, slow	More, quickly Less, slowly	High non–Organization of the Petroleum Exporting Countries (OECD) economic growth Low non-OECD economic growth
15	Resources/energy—gas or carbon tax	Constant	Taxes increased	Bills already introduced Economic growth and attitude change
16	Resources/energy—price	Volatile	Higher price Lower price	High economic growth and restricted supply Low economic growth and expanded supply
17	Road freight (amount and proportion)	More, medium	More, fast	Alternative freight movement systems
18	Security	More, medium	More, fast	Decrease in funding, technology, coordination Increase in funding, technology, coordination

No.	Driver	Expected Changes	Alternative Changes	Rationale for Alternative Changes
19	Technology—physical and fixed	More, very slow	Less, medium	Decrease in funding Increase in privatization and PPPs Rise in number of cyber attacks
20	Technology—IT	More, fast	Less, fast	Decrease in funding Increase in privatization and PPPs Rise in number of cyber attacks
21	Transportation choices/complexity	More, fast	Less, medium	Decreasing urbanization and density, moderate or low gas prices

CHAPTER 6: SCENARIO DEVELOPMENT AND MULTI-DRIVER SCENARIOS

In the work described in the previous chapter, the research team held a workshop and identified 21 drivers that will substantially impact the future. The team used these drivers as the basis for developing expected and alternative futures and six multi-driver scenarios, discussed in this chapter.

This chapter focuses on the following steps, which complete Task 4: Scenario Development:

- **Step 11: Describe the Expected Future (Baseline).** The research team elaborated on the expected future for each of the 21 key drivers.
- **Step 12: Describe Alternative Futures.** The research team elaborated on the alternative futures for each of the 21 key drivers.
- **Step 13: Develop Multi-driver Scenarios.** The research team created multi-driver scenarios in narrative form.

Figure 6.1 shows the steps discussed in this chapter.

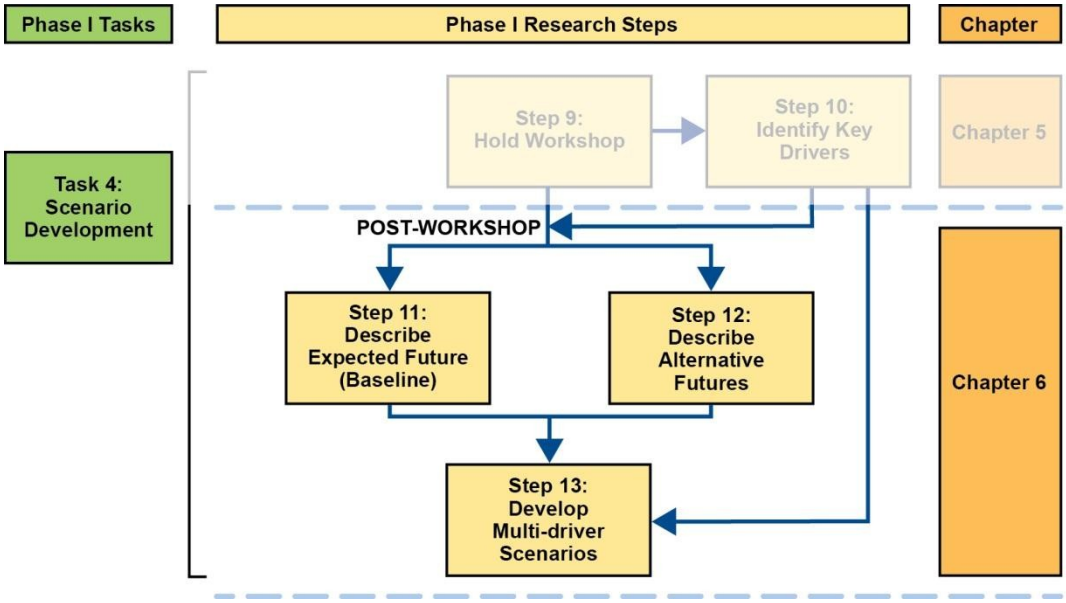

Figure 6.1. Research Process Discussed in Chapter 6.

The material presented in this chapter was developed by the team's futurists using scenario planning tools. The information developed from Task 4 forms the basis for the Phase II assessment of the six transportation areas and future strategies.

EXPECTED FUTURE (BASELINE)

As shown in figure 6.1, step 11, the scenario planning technique requires the researcher to identify the expected future trend and the rate for the trend for each driver. The trend indicates the direction of change, and the rate suggests the magnitude of the change in that direction. For example, the researcher may identify a trend that suggests a positive change in economic growth, but the rate of change is slow.

The expected future focuses on an assessment of the trend and rate for the driver. This expected future is the baseline. If present trends continue, current plans are fulfilled and existing projections are correct.

Several of the 21 drivers shown in table 5.1 have a common driver theme. Those drivers with a common theme are covered under a single description of the expected future. These include:

- Funding (amount [#4] and proportion private [#5]).
- Government role (large/small [#6] and federal/state/local [#7]).
- Mobility (demand [#8], capacity and access [#9], and expectations for mobility [#10]).
- Resources/energy [supply [#13], demand [#14], gas or carbon tax [#15], and price [#16]).
- Technology (physical and fixed [#19] and IT [#20]).

The following subsections provide a narrative description of the expected baseline futures for each of these themes of drivers.

Climate Change (Driver #1)

The trend is more; the rate is moderate.

Temperatures are predicted to continue to rise at a rate of 0.2°C per decade for the next two decades. The best estimated temperatures vary from an increase of 1.8°C to 4.0°C. On average, the temperature is predicted to increase 1.6°C by 2050.

Increasing global average temperatures will result in a variety of altered weather patterns and situations that will affect the operation and maintenance of the U.S. highway system.

Some of the most likely weather pattern changes include more frequent extreme temperatures, a changing range of maximum and minimum temperatures, changes in precipitation levels, increased intense precipitation and other storm intensity, rise in soil erosion and related dust, rising sea levels, and increased hurricane intensity.

Highway infrastructure and operation could include a premature deterioration of infrastructure, flood damages to the infrastructure in the flood plain or coastal areas, accelerated degradation of bridges due to rising sea levels, and increases in bridge and infrastructure failure due to more intense hurricanes. For full information, see NCHRP 20-83(05) *2.3 Synthesis Report*.

Economic Growth (Driver #2)

The trend is some; the rate is slow.

U.S. economic growth remains slow overall, with some industries experiencing a flat or declining trend over the next 40 years (e.g., manufacturing industries see a decline, and other service-related industries see moderate growth). The demand for improved mobility and congestion relief continues, but funding for the highway infrastructure system is primarily used for maintenance and rehabilitation needs. Meanwhile, traditional funding sources, such as gas tax revenues, become inadequate to keep pace with system demands.

The trade deficit continues to widen, and movement of goods and services from port to border, such as through the port of Long Beach in Southern California, become an area of national strategic focus. The transportation system, including highway, rail, and transit, that provide access to ports become a priority for federal funding participation. Limited space for new system improvements drives innovation in use of managed lanes, elevated freeway systems, and increased use of real-time traffic monitoring capabilities.

Priority on Environmental Quality (Driver #3)

The trend is more; the rate is medium.

Researchers anticipate that there will be increased priority on environmental quality in the future. Within society, signals point to increased awareness and emphasis on maintaining and preserving our environment—from an increase in the number of communities with recycling programs, to the growth of regional sourcing markets associated with the *locavore* (a person who eats food produced locally, not moved long distances to market) movement.

New technologies are rising to meet the challenges of both regulatory requirements and the public's desire for more environmentally friendly choices for transportation. The next 50 years will see a marked increase in the number of alternative-fuel vehicles that will be available and affordable.[18]

Highway-focused, context-sensitive design solutions are also expected to increase in demand and application as some agencies offer incentives to develop green elements. It is likely that advances in recycling efforts will result in more pavements made from these materials. Such efforts could be derailed or slowed down as traditional funding mechanisms limit the ability to meet rising environmental sustainability expectations and goals.

Funding (Drivers #4 and #5)

For "amount," the trend is less; the rate is fast. For "proportion private," the trend is more; the rate is medium.

Trends in transportation funding will be affected by two primary subdrivers: the actual amount of funding and the proportion of private to public funding invested in transportation.

The outlook for the amount of funding available from fuel taxes in the long term is increasing but with diminishing growth rates. The Transportation Research Board (TRB) estimates that through 2025 and beyond, growth in vehicle miles traveled will outpace growth in fuel consumption. Fuel-based revenue growth rates are expected to be suppressed based on trends in rising fuel prices, new automotive technologies related to combustion engine efficiency, the role of alternative fuels, and new environmental and energy regulations that push down fuel consumption even as use of the roadway network increases.

There is an increased outlook for the rise in private-sector participation in the provision of infrastructure assets for the operation, maintenance, and financing of new and existing infrastructure including highways. The privatization of infrastructure can transfer public risk, accelerate project delivery schedules, provide performance-based platforms for service delivery, allow operators to focus on life-cycle costs, and maximize capital formation and potential

payments to the public sector. However, some of the primary drawbacks include potential shifts in regional mobility (especially in the case of privately leased roadways that may divert traffic to non-tolled alternatives) and loss of control over public assets.

Government Role (Drivers #6 and #7)

For "large/small," the trend is smaller; the rate is slower. For "federal/state/local," the trend is less federal; the rate is slow.

The long-term outlook for the relative roles of federal, state, and local entities in transportation policy is a slowly decreasing role for the federal government. This long view is supported by shifting attitudes with regard to regulation and a gradual increase in preference for state and local control. Policy makers and transportation practitioners have called to consolidate the vast number of transportation-related programs and focus on a few core areas of transportation policy. Funding would then be allocated based on new, performance-based formulas or on a competitive basis. The end result of this development will be a reduction in the influence of the federal government in terms of allocating revenues (and thus influencing transportation policy at the state and local level) to key components of transportation policy, namely connectivity, access, and system sustainability. State and local entities will be given increased latitude in developing their own transportation policies so long as they fall within the reduced scope of the federal government.

Mobility (Drivers #8, #9, and #10)

For "demand," the trend is more; the rate is medium. For "capacity and access," the trend is more; the rate is slow. For "expectation for mobility," the trend is more; the rate is slow.

The expected trend in mobility is more demand at a medium rate and more capacity at a slow rate. Population growth will occur in absolute numbers, and by extension will have an effect on the growth in highway demand. Consistent with current trends, population is shifting from rural areas to urban, and high levels of population growth in densely developed areas will create greater concentrations of highway demand while simultaneously creating more favorable opportunities for transit.

The level of population density will affect the supply of roads and transit, congestion levels, prices, distribution of destinations, and accessibility by nonmotorized modes. Most freight in the United States is currently moved by truck, as much as five times the amount moved by rail. Truck volumes are approaching very high levels on the interstate highway system and are projected to continue to increase. The average interstate highway mile carries 10,500 trucks, which will rise to 22,700 by 2035.[19]

In the future, Americans will have an expectation of mobility and transportation choices. But this trend will continue at a slow pace as people recognize the challenges associated with expanding the transportation network within the built urban environment. The transportation sector will respond by offering more multimodal options, capacity expansions where feasible, and increased technology to offer alternatives to commuting to a workplace.

Population Density (Driver #11)

The trend is more; the rate is slow.

The expected trend in population density is toward higher density, growing at a moderate rate. The 2010 U.S. Census provides support for the notion that while central city populations have grown in the last decade, most of the growth has occurred in suburbs surrounding the growing cities of the south and west. Many of the counties with the highest population loss rate (48 counties with over a 17 percent loss) are predominantly rural areas or small towns. A continuation of these trends points to higher concentrations of population in urban areas, continued dispersed development on the urban fringe, and declining population in rural areas. As a result, the highway infrastructure will have two distinct elements. High levels of population growth in densely developed areas will create greater concentrations of highway demand while simultaneously creating more favorable opportunities for transit. Conversely, low levels of population growth in more dispersed urban forms will create lower concentrations of demand and a more extensive network of infrastructure. The level of population density will affect the supply of roads and transit, congestion levels, prices, distribution of destinations, and accessibility by nonmotorized modes.

Public Commitment to Sustainability (Driver #12)

The trend is more; the rate is slow.

The U.S. population has slowly gained interest in engaging in sustainable practices over the previous decade. Businesses shifted to including sustainability as a part of their strategic plans, cities considered and passed taxes on plastic grocery bags, and consumers increasingly used reusable green shopping bags at the supermarket. This relatively new phenomenon seems likely to continue to slowly grow in acceptance among the general public as socially conscious younger generations move into the workforce. The general acceptance of sustainability is also likely to increase due to the increasing presence and visibility of climate change as an *umbrella issue*. The changes in weather patterns, increases in sea level, and stronger storms will create a visible pattern that will provide the impetus to encourage society to engage in more sustainable development.

An increased public acceptance of sustainability will translate into more sustainable actions by governments and businesses. Companies and governments will be more concerned with ensuring that the public sees that their business practices are sustainable. Private transportation will begin to shift to include more vehicle sharing, carpooling, and use of more efficient vehicles. Public transportation will become more popular, and usage will increase. State DOTs and local governments will need to meet the demand citizens make for increased interest in sustainable practices. Transportation planning will need to ensure that present and future generations' needs are met while balancing the demands of economic growth, environmental protection, equity among populations, and quality of life. Although it is unlikely that true sustainability will ever be met, the public's increased acceptance of it will encourage a greater emphasis on adhering to its tenets.

Resources/Energy (Drivers #13, #14, #15, and #16)

For "supply," the trend is more; the rate is slow. For "demand," the trend is more; the rate is slow. For "gas or carbon tax," the trend and rate are constant. For "price," the trend and rate are volatile.

The long-term supply, demand, and price of energies can be difficult to accurately forecast due to the interaction of many variables that shape the market. Geopolitical events, economic forces, technological innovations, and many other factors regularly impact energy markets, and each has the potential to drastically alter long-term energy sales.

The international liquid petroleum supply is split between countries in the Organization of the Petroleum Exporting Countries (OPEC). OPEC members currently represent about 40 percent of world production, and non-OPEC sources make up about 60 percent.

Concerning supply, the Energy Information Agency (EIA) predicts that:

- The total international supply of oil will increase by 29 percent, from 85 MBPD in 2009 to 111 MBPD in 2035.
- 38 percent of the growth is projected to arise from increases in unconventional production techniques, including growth in both OPEC and non-OPEC states.
- A small amount of growth will also occur in the production of alternative liquid fuels.

Concerning demand, EIA predicts that:

- Total global demand will increase from 83.7 MBPD in 2009 to 110.8 MBPD by 2035, an increase of 27.1 MBPD (or 32 percent).
- Domestic demand will increase from 18.8 MBPD in 2009 to 21.9 MBPD in 2035, an increase of 2.9 MBPD (or 15 percent).
- Non-OECD demand for oil will account for the largest amount of total demand growth, with consumption increasing from 38 MBPD in 2009 to 62.5 MBPD, or an increase of consumption by 24.5 MBPD (or 64.4 percent). Much of the growth occurs in China (9.3 more MBPD), India (2.6 more MBPD), and the Middle East (4.38 more MBPD).

The price of oil is largely a function of the levels of demand and supply coupled with some other forces, such as speculation on future oil supply and demand. Domestic costs are also determined by the level of taxation. The EIA reference case predicts that the price per barrel of imported low-sulfur light crude oil will increase to $124.94 in 2009 dollars, or a nominal price of $199.37.

Throughout this time period, it is likely to see volatile prices for oil since the market is characterized by an inelastic supply and demand for oil in the short term. Relatively minor disruptions in the supply of oil can lead to large increases in price.

As the price of oil increases, consumers will reduce the total amount of vehicle miles traveled (VMT) as a response to high prices. They will attempt to find alternative means of transportation or will shift to purchasing more fuel-efficient vehicles. The cost of goods will increase because producers will pass on the high fuel costs to consumers. Highway construction and maintenance may become much more costly because many of the current construction materials are derived or dependent upon petroleum products. The high fuel costs will create strong incentives for

innovations that reduce petroleum usage in many different markets. Alternative fuels will become more competitive as the price of oil increases, enabling greater innovations and encouraging private and public investments.

Road Freight (Driver #17)

The trend is more; the rate is medium.

The demand for freight movement is expected to grow based on the slow expansion of the domestic and global economy. Furthermore, as future populations concentrate in large urban centers, so does the need for freight movements, in particular from farm to market and from manufacturing centers within a metropolis to other metropolitan centers.

Continued expected growth in truck-based freight will result in increased pressure on regulators to confront negative impacts on highways and bridges stressed by increasing gross truck weight. Thus, significant capacity improvement of the present trucking system seems unlikely.

Multimodal systems are expected to evolve as the most efficient way to handle freight. These multimodal hubs may be based around coastal or inland ports and airports. These high-volume assets are already quite efficient because their owners have historically been early and widespread adopters of automation technologies such as web-enabled robotics for packing/stacking (e.g., Kiva Systems), unpacking, satellite tracking, and inventory routing.

It is likely that the U.S. Postal Service and post offices worldwide will go out of business in the next decade or so. Replacing this will be a unitized private-sector parcel service, much like the present UPS®, FedEx®, etc., but with a much greater weight and dimension capability. Container transportation will also continue to be the preferred method of freight transport, but robotics will be used to pack/unpack goods.

Security (Driver #18)

The trend is more; the rate is medium.

The current trend is not only an increase in the number of threats in the United States but also an increase in the number of threats internationally. Assuming that the current trend continues, future terrorist attacks will be more organized and more intelligent, with potentially greater damages and prompting an increased level of security measures. The expectation is that these attacks will continue to be in a form that destroys physical assets and innocent people, making vehicles and highway infrastructure a major target. Cyber attacks are also expected to continue, such as those perpetrated by the globally distributed hacker groups Lulzsec and Anonymous.

Technology (Drivers #19 and #20)

For "physical and fixed," the trend is more; the rate is very slow. For "IT," the trend is more; the rate is fast.

Technology in the domain of this study can be largely categorized as either extrinsic or intrinsic with respect to transportation in general or the transportation infrastructure in particular.

Intrinsic technology (i.e., transportation-related technology) is predominantly initiated and funded by the public sector. With diminishing federal and state budgets and as the pressure to maintain and rehabilitate the existing highway infrastructure remains high, the transportation agencies will need compelling reasons to invest in new and innovative technologies.

Extrinsic technologies can be thought of as led by the private sector—often by well-known technology companies for commercial gain in general and independent of any particular purpose. Such companies may include, but are not limited to, Microsoft®, Apple®, Motorola®, Sony®, Samsung®, Facebook, and so on. In essence, extrinsic technologies (e.g., Google Maps®) are developed not with the intention of solving a specific transportation system problem but are adapted later for transportation use.

There are many striking futuristic examples of extrinsic technologies such as Google's driverless car project, rise of web-based standards such as Robotic Operation System Java (ROSJava), and off-the-shelf commercialization of key systems such as light detection and ranging (LIDAR) that create the possibility that technological capability within as little as 10 years could lead to more widespread adoption.

Safety improvements can be achieved by regulations. For example, the government could require that by 2020 all cars and trucks be fitted with proximity warning devices, dead-man brakes, speed-limiting devices, adaptive cruise control, etc. Capacity improvements could be achieved by smart traffic signals and routing. A more ambitious approach would be to develop autonomous driverless cars. The National Highway Traffic Safety Administration (NHTSA) continues to create market certainty for automakers around five-star ratings based on collision warning and avoidance systems. Nevada is expected to become the first state to allow real-world testing of autonomous vehicles.

Therefore, the expected future will be composed primarily of the private sector leading the way in developing technologies that are both extrinsic and intrinsic to the highway system. Both federal and state governments will rely heavily on the private sector to investigate and invest in technologies that can be adapted and adopted to solve transportation-system problems. Thus, the rate and direction of change for technology may be a slow increase.

Transportation Choices/Complexity (Driver 21)

The trend is more; the rate is fast.

Over the next few decades, consumers will begin to demand more choices and mobility options for a variety of reasons. First, congestion will slowly increase, creating incentives for individuals to find faster and more efficient modes of transportation. Urbanization and the overall density of development will also increase, which will only further exacerbate the problems created by congestion. Additionally, the rising cost of gasoline will provide more incentives for individuals to find alternative forms of transportation.

Cities and states will begin to integrate more options and modes into the infrastructure, satisfying the increased demand for mobility. These options will vary across areas depending on the specific needs of the area and political willingness. Some areas will integrate alternative modes directly into the highway system by either dedicating lanes or accommodating some modes by building special facilities. These integrated systems will likely use passenger rail, freight

shuttles, managed lanes, bus systems, or other means. Other areas may provide similar options but separate from the highway system.

ALTERNATIVE FUTURES

As with the expected baseline future, the research team developed narratives for alternative futures (step 12 in figure 6.1). Alternative futures are what may happen instead of the expected future. As shown in table 5.1, the workshop identified one or two plausible alternative futures for each of the 21 drivers, including the trend, rate, and rationale for each.

The following subsections provide a narrative description of the alternative futures for each of the themes of drivers.

Climate Change

The trend is more; the rate is high.

A higher-temperature scenario is characterized by temperatures at the end of the 21st century increasing by 4.0°C and temperatures by mid-century increasing by about 1.6°C. This scenario will likely occur as a result of very rapid economic growth, population growth peaking at mid-century, rapid development and implementation of new and more efficient technologies, and intensive usage of fossil fuels. The GHG emission levels are significantly higher than both the moderate scenario and the current emission levels. A higher-temperature scenario will likely have much more intense effects on the highway system than the moderate-temperature scenario.

Economic Growth

The trend is more; the rate is fast.

The U.S. economic growth remains slow through 2020, partly due to the great recession that started in 2006 and continued for well over a decade, and then realizes gradual to strong increases thereafter. Economic re-growth after 2020 is primarily supported by innovation in alternative energy sources and advances in information technology. The United States becomes a leader in developing alternative clean energy that leads to global change in the use and choice of alternative energy sources. Coordination improves with other transportation modes, such as high-speed rail and local transit agencies. After 2025, many of the U.S. bridges and other transportation structures are approaching the expected design life or become functionally obsolete. Twentieth century funding sources for highway infrastructure became inadequate to keep pace with system demands. In 2050, with the increase in use of electric and hybrid fuels, the gas tax becomes obsolete as a sustainable funding source. An increase in road user fees, such as toll roads and toll bridges, and alternative procurement methods of delivery such as PPPs become the dominant funding sources for highway improvement projects.

Federal and state funding sources for transportation remain but at less than current participation levels. The improved economy of the mid-21st century leads to an increase in federal policy and participation in highway improvement projects. The movement of goods and services from port to border becomes a national strategic focus. The transportation system, including highway, rail, and transit, that provide access to ports becomes a priority for federal funding participation.

Priority on Environmental Quality

The trend is less; the rate is medium.

Increased environmental regulation in the first decade of the 21st century heightened awareness of environmental issues and the need to put a priority on them. Some states, such as California, have enacted very aggressive climate-change laws. Over time, though, the regulations are perceived to be burdensome and have hindered implementation of much-needed transportation projects. The pursuit of legal action also indicates a plausible trend toward slowed economic growth due to environmental policy. A case in point involves Chevron and a collection of Amazonian tribespeople in Ecuador. If the verdict is upheld, Chevron will pay a $9.47 billion fine, the highest damages award in an environmental case.[20] The case is being appealed. In the meantime, Chevron no longer holds any assets in Ecuador.

Under this alternative future, the cost of environmental regulations hinders economic development and becomes a drag on the economy. In the case of oil drilling, regulations have reduced the amount of drilling that occurs domestically, which increases the reliance on foreign sources. This exacerbates our trade imbalance. The effect of this on the transportation sector is that very little research funds are available for testing new technologies, and the private sector, once an important partner in building infrastructure, simply finds it too expensive to do business in America. Thus the economy suffers even more. More jobs, especially in the manufacturing sector, move overseas or to other states with less regulation. The result is a perpetual drag on the economy. The public sees burdensome environmental regulation as a barrier to economic recovery.

While there is still a desire to be environmentally responsible, the pendulum swings in the opposite direction of regulation. Consequently, little is done to mitigate congestion. Major urban areas still experience peak-hour congestion even in the slow-growth economy. Lack of funding has stymied research, and a stagnant economy perpetuates the status quo. Although some advances are made in construction technology, the transportation sector stays much the same, with congestion increasing in urban areas, multimodal alternatives lagging in investment, and few nonmotorized alternatives.

Funding

For "amount," the trend is more; the rate is slow. For "proportion private," the trend is more; the rate is medium.

In this alternative, investments in public infrastructure by federal and state entities will increase as a percentage of GDP. This investment will occur due to several factors, but the immediate result is an increase in infrastructure development by these entities and a flattening of the level of participation by private enterprises. It is unlikely that the level of private-sector participation in infrastructure provision will decrease, especially given the long concession periods of current PPPs and related arrangements.

Government Role

For "large/small," the trend is more; the rate is medium. For "federal/state/local," the trend is more federal; the rate is medium.

In this alternative, the role of the federal government in terms of directing transportation policy and otherwise regulating the transportation sector is greatly enhanced. State and local entities have less control over how funding is spent because of the presence of numerous funding categories with their own unique stipulations and requirements.

Mobility

For "demand," the trend is more; the rate is slow. For "capacity and access," the trend is more; the rate is moderate. For "expectation for mobility," the trend is less; the rate is slow.

An alternative trend in mobility is more demand growing at a low rate, coupled with more highway capacity growing at a moderate rate. In spite of demand growing at a greater rate than increase in highway system capacity, highway demand in this alternative is managed through investment in mass transit and alternative freight movement systems; advancements in vehicle technology that reduce headways and more effectively use available capacity; widespread use and acceptance of demand management techniques, including congestion pricing; and socio-demographic influences that modify the way people live and work, thus reducing the need for highway travel.

In this alternative, due to continued concerns over the jobless rate, deficit spending, and the overall stagnant economy, no investment is made in transportation of any mode. Over time, congestion increases in major urban areas, with peak periods of congestion stretching to several hours of the day. Freight movements are hindered by congestion, adding to the cost of goods. The public is strongly opposed to any alternative revenue sources such as tolling, pricing, or privatization. There is no investment in alternative modes. As a result, infrastructure deteriorates almost to a state of complete disrepair. Only a few interstate routes are able to be maintained for goods movement. Because of the road conditions, people drive even less, which leads to even more decreasing revenues, creating a cycle. Outside of urban areas, there is little to no mobility because these areas have been left to the local governments to maintain, yet they have no funding available for maintenance either.

Population Density

The trend is less; the rate is medium.

An alternative trend in population density is toward a lower-density, dispersed population, growing at a moderate rate. This alternative model is one of greater decentralization, where growth occurs in small towns, suburbs, and second-tier cities outside the established metropolitan areas. Small towns and mid-range cities grow, and suburban and exurban areas around cities continue to grow in both employment and residences.

Public Commitment to Sustainability

The trend is less; the rate is slow.

One factor that affects public acceptance of sustainability is the state of the economy. When the economy is not growing, the public tends to focus on regaining economic prosperity as their most important priority. This focus on one priority runs against the idea of sustainability. Inherent in the concept of sustainability is the need to balance the demands of economic growth, environmental preservation, and equity among populations—for the present and future generations. If the country experiences perpetual economic stagnation or negative growth, it is likely that the public will focus on growing the economy at the detriment of other objectives. If the current economic conditions continue to occur, it is likely that the public will not place a high priority on sustainability, and acceptance of sustainable development will diminish.

Resources/Energy

This theme of drivers has a combination of multiple alternatives.

The EIA includes high- and low-cost oil scenarios in their projections as a result of varying levels of economic growth in non-OECD countries and oil supply restrictions or expansions. The high-oil-price scenario assumes higher than expected economic growth in non-OECD countries and restrictions on the supply of oil. High demand and low supply of oil occur, resulting in higher prices. In this scenario, oil prices in 2035 are projected to rise to $200 per barrel in 2009 dollars. The low-cost scenario assumes lower than expected growth in non-OECD regions and a large increase in the production of oil. The coupling of decreased demand for oil and an increased supply drive down prices to $50 per barrel in 2009 dollars.

One situation that could change the pattern of oil markets in the future is the advent of a backstop fuel that is readily available, is economically efficient, and has low adoption costs. Such a fuel could be a substitute fuel for many of oil's current uses, once oil reaches a constant price level above which the backstop fuel is economically efficient to use. Speculations abound about what type of fuel might prove to be the backstop fuel, including renewable energies, coal, natural gas, electricity, and other potential energies. For example, this sort of scenario could arise should nuclear fusion become technologically viable and economically efficient to generate electricity. Producers would have to develop effective and efficient vehicles, and consumers would purchase them to take advantage of the inexpensive fuel.

Carbon Pricing

Currently, there is no carbon-pricing mechanism in the United States. The two most likely manifestations of such a system would be either cap and trade or a carbon tax. There have been several pieces of legislation that would enable such a system, most notably the American Clean Energy and Security Act of 2009. The act would have implemented a cap and trade system for carbon dioxide. The bill passed the House of Representatives but died in the Senate.

Should a similar piece of legislation pass in the future, it would—depending on the specific tenets of the legislation—increase the cost of gasoline and other carbon-based fuel sources. This would create a long-run decrease in overall domestic demand for products that use carbon. Producers that traditionally use carbon-based fuels or expel a large amount of carbon would

attempt to find alternative production means to decrease costs. A carbon-pricing system would increase the costs to drive for motorists who use carbon-based fuels for transport (including electric-based vehicles that use electricity generated from carbon-based sources). As a result, motorists would be incentivized to drive less and switch to transportation modes that use less carbon.

In the current outlook, it is unlikely that a similar piece of legislation will be passed. Two large shifts would need to occur to increase the chances of passage: the economy would need to make a strong recovery, and Americans would need to shift away from the propensity to frame tax increases as an inherently negative proposition.

Road Freight

The trend is more; the rate is fast.

When the economy booms, there is a marked increase in demand for freight transportation services. However, because success breeds success, there is sufficient capital available, and investments in infrastructure are seen to be sound. Consequently, there is considerable private-sector investment in infrastructure via pension funds, bonds, and other capital market instruments. All existing modes of transport are expanded. Moreover, due to promising return on investment, some exotic new forms of private-sector-led freight-only transportation infrastructure are established. One example of this would be the TTI Freight Shuttle that is proposed for use in cross-border transport of containerized goods, as well as an alternative inter-city main-trunk linkage transshipping container boxes. This proposed system is considered particularly efficient where inter-city distances are in the range of 200 to 600 miles.

As the economy expands and the U.S. pre-eminence in technology innovation compounds, there will be many associated benefits in transportation efficiency. Robotics will abound, and scheduling and dispatching are fully automated. As the systems become increasingly efficient, diverse, and redundant, there is less need for the transportation system to expand at the same rate as the demand. Through technology, these adaptive systems are able to do more with less.

Security

The trend is more; the rate is fast.

In this scenario, a rise in funding allows the United States to invest in more research and development, human resource training, and rehabilitation of critical infrastructures. Cutting-edge research allows for innovative methods to detect and predict terrorist efforts in advance of execution or to provide ways to minimize the negative effects. Examples may include smart prediction tools that can accurately detect cues and early warning signals of terrorist movement and development, stronger materials that can withstand more powerful attacks, advanced combat robots that can virtually replace humans, and advanced satellites that provide more powerful images and detect movement of terrorist group activities.

Investing in human resources will be another way to strengthening the security of the nation by investing in intellectual capital. Although this may be the trend for the current situation, the alternative situation allows for a higher intensity of training, leading to a higher probability of

recognizing and capturing terrorists, stopping illegal immigrants, and strengthening cyber security.

Finally, this scenario will offer enough funding to rehabilitate and strengthen the current critical infrastructures that need significant improvements for reliable serviceability. This scenario assumes that there will be stronger materials that can withstand stronger and sudden attacks.

Technology

For "physical and fixed," the trend is less; the rate is medium. For "IT," the trend is less; the rate is fast.

Technology improves in every sector, but there is some discontinuity between the flow and accuracy of information and issues with interoperability. Suppose the U.S. economy collapses (see Crisis World or Dirty World in chapter 4); technology development in transportation grinds to a standstill. Public- and private-sector initiatives are diverted into either Homeland Security or Department of Defense initiatives.

A lack of security will lead to frequent cyber attacks, which will cause people to become skeptical of technology and prevent it from becoming ubiquitous. In this alternative scenario, a lack of development of supporting technologies and platforms may eventually cause horrific accidents in autonomous vehicles, leading to intractable litigation and abandonment of certain high-end technologies. Consequently, the government and the public become disenchanted with technology and see little need to invest in technology improvements.

Transportation Choices/Complexity

The trend is less; the rate is medium.

It is possible that expected changes will not occur, but instead that individuals will become more dependent on their personal vehicle for transportation. This would likely occur as a result of decreasing urbanization and density, coupled with lower gas prices. Businesses would continue to locate on the peripheries of cities to accommodate workers who do not want to commute into urban centers. This type of development would require a greater amount of roadway infrastructure built over progressively larger areas. It would have the effect of increasing costs for construction, operation, and maintenance of the highway infrastructure.

MULTI-DRIVER SCENARIO DEVELOPMENT

The July workshop, as discussed in chapter 5, identified the drivers (forces) that will influence the future of highways over the next 30 to 50 years. Each of those drivers is expected to behave in a particular way over that time period. Those expectations are described in the baseline or expected future, the most likely scenario to occur compared to any other scenarios. The baseline future is not probable in the strict mathematical sense, that is, more than 50 percent probability of occurrence. It is simply more likely than any of the other individual scenarios, but it is not more likely than all the other scenarios combined.

The baseline future rests on a set of assumptions. The most common assumptions are that present trends will continue at the same rate throughout the forecast period or that stakeholders will achieve their announced intentions and goals before the time horizon. Those assumptions are

more likely than their alternatives, yet all assumptions can be challenged, some successfully and some not so successfully. A successful challenge is an alternative that could plausibly occur instead of the original assumption. Each of those plausible alternative assumptions is described in the single/multiple-driver alternative futures. Taken together, they represent the uncertainties that forecasters and planners in the U.S. transportation system should be aware of and—if important enough—take measures to prepare for.

The future, however, does not occur one driver at a time. Rather, all the drivers are integrated into and will shape the future that does occur to some extent. The last step in scenario forecasting, therefore, is to develop a few integrated scenarios that illustrate the range of alternative scenarios that transportation agencies face (see step 13 in Figure 6.1).

It would be easy to list all possible scenarios for just a few drivers and a few alternatives per driver. In fact, the most popular scenario technique, the Shell/GBN technique, developed by the strategic planning unit of the Royal Dutch Shell Corporation[21, 22] and popularized by Peter Schwartz in *The Art of the Long View*,[23] uses only two drivers (dimensions of uncertainty) and two alternatives per driver. The result is a 2×2 matrix of four alternative scenarios, a quite manageable number. The problem with the Shell/GBN technique, however, is that the future of any real domain is shaped by many more than two drivers. The list of all the combinations of N drivers with two alternatives each is 2^N, a number that grows quite rapidly for a realistic set of drivers. In this case, the TTI workshop identified 21 individual drivers which produce over 2 million possible combinations of uncertainties, a number that is far too large to handle in any closed analytical fashion.

In fact, integrating the large number of uncertainties uncovered in most scenario projects into a handful of meaningful scenarios has presented conceptual difficulties to futurists all along. This study therefore will attempt to bridge that divide by identifying the pairwise relationship between each of the 21 drivers and using that relationship as the input to a factor analysis that identifies drivers that tend to operate in a similar fashion. Those groups of drivers can then be used as the basis for developing a manageable number of scenarios.

Factor analysis is not a common technique in the development of scenarios. Wang[24] used a factor analysis to group potential events and outcomes related to the future of China's relation with Taiwan rated on the likelihood of their occurrence. Items that were rated in a similar way, however, may have no substantive relation with each other. They were just rated as equally probable by the sample of respondents. It is hard to see how those factors would be the basis of a consistent set of scenarios.

The process employed in this research is to create a cross-impact matrix among the 21 individual drivers identified in the workshop. Each driver has an expected future based on current trends and plans and one or two alternative futures based on a reasonable judgment that the driver could behave in an unexpected yet still plausible manner.

The resulting 21×21 matrix is listed in table 6.1; table 6.2 gives a summary of the effects of the driver listed vertically (in row headers) on the drivers listed horizontally (in column headers). Each cell in the matrix indicates the degree to which a change in the row driver would impact the column driver. A plus sign (+) indicates that an increase (or decrease) in the row driver would produce a change in the same direction in the column driver. A minus sign (−) indicates the

opposite, that a change in the row driver would produce a change in the column driver but in a different direction. An empty cell means that the variables are not directly related.

The next step is to treat this matrix as a set of data where the rows are the variables and the columns are the data. In order to calculate a correlation matrix based on these data (that shows how the drivers are related to each other in a pair-wise comparison), the symbols in table 6.1 are replaced with numbers. A plus sign is replaced with +1, a minus sign with a −1, and a blank with 0. A row-wise correlation matrix can then be generated, indicating which variables tend to have similar ways of impacting the other variables. This matrix is produced in table 6.3.

The correlation matrix does show pair-wise relationships, but it is still too complex to identify a handful of scenarios. Therefore, the correlation matrix is used as input to a factor analysis, which yields a small number of factors that indicate the primary relationships among the variables.

The factor analysis required that three pairs of variables be combined since they had identical or near-identical impacts on the other variables. The three pairs were:

- #6 government role—large/small and #7 government role—federal/state/local: The assumption was that a large government role would most likely be implanted by the federal government more than by state or local governments.
- #8 mobility—demand and #10 mobility—expectations for mobility: The assumption was that demand and expectation mean almost the same thing. There is no substantive difference between mobility demand (the need for people to get from one place to another) and mobility expectations (the belief that one can do that efficiently). They are not identical, but the assumption was that these two variables will converge toward each other over time so that they will not have any different impact on the other variables.
- #3 priority on environmental quality and #12 public commitment to sustainability: Both of these are similar political positions in today's environment.

The result was that the matrix now includes 18 drivers instead of the original 21.

A factor analysis clusters the variables that have similar correlation coefficients in the correlation matrix. Each of the variables "loads" onto the factor with a certain weight, called the factor loading:

- Relatively high positive factor loadings (greater than 0.30) indicate that those variables have relatively high positive correlations with each other. In other words, their changes tend to move in the same direction.
- Low negative factor loadings (less than −0.30) mean that those variables have relatively high negative correlations with the other variables loading on the factor. In other words, they tend to move in opposite directions from the variables that load positively.

Table 6.1. Cross-Impact Matrix.

Cause (Driver)	Effect																				
	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Climate change		−	+			+	+					+	−	−	+						
2. Economic growth	+		−	+	+			+		+	−	−	+	+		+	+		+	+	+
3. Priority on environmental quality	−	−		−		+	+	−	−	−	+	+	−	−	+	+	−				+
4. Funding—amount		+							+								+		+	+	+
5. Funding—proportion private				+		−	−														+
6. Government role—large/small	−	−		+	−		+		+						+			+	+		+
7. Government role—federal/state/local	−	−		+	−	+			+						−			+	+		+
8. Mobility—demand	+		−		+	+	+			+		−		+		+					+
9. Mobility—capacity and access		+						+		+	−			+		+					
10. Mobility—expectation for mobility	+		−		+	+	+	+				−		+		+					+
11. Population density		+						−		−				−							
12. Public commitment to sustainability	−	−	+	−		+	+	−	−	−	+		−	−	+	+					+
13. Resources/energy—supply	+	+				+										−					+
14. Resources/energy—demand																+					
15. Resources/energy—gas or carbon tax	−	−		+		+	+	−		−	+			−		+	−				
16. Resources/energy—price		−	+					−		−	+	+	+	−	−		−			+	
17. Road freight	+	+																			
18. Security		+		−																	
19. Technology—physical and fixed		+							+												+
20. Technology—IT	−	+						−	+	−								−	+		+
21. Transportation choices/complexity									+		−										

* Numerals in this row correspond to the names of the variables listed in the first column.

Note: Plus sign (+) means positive correlation; minus sign (−) means negative correlation; grey cell means not applicable; empty cell means the variables are not directly related. For example, climate change (cause #1) decreases economic growth (effect #2) and supply and demand of resources/energy (effects #13 and #14), and increases priority on environmental quality (effect #3), government role (effects #6 and #7), public commitment to sustainability (effect #12), and gas or carbon tax (effect #15).

Table 6.2. Summary of the Effects of the Scenario Drivers.

#	Cause (Driver)	#	Increases	#	Decreases
1	Climate change	3 6 7 12 15	Priority on environmental quality Government role—large/small Government role—federal/state/local Public commitment to sustainability Resources/energy—gas or carbon tax	2 13 14	Economic growth Resources/energy—supply Resources/energy—demand
2	Economic growth	1 4 5 8 10 13 14 16 17 19 20 21	Climate change Funding— amount Funding— proportion private Mobility— demand Mobility— expectation for mobility Resources/energy—supply Resources/energy—demand Resources/energy—price Road freight Technology— physical and fixed Technology—IT Transportation choices/complexity	3 11 12	Priority on environmental quality Population density Public commitment to sustainability
3	Priority on environmental quality	6 7 11 12 15 16 21	Government role—large/small Government role—federal/state/local Population density Public commitment to sustainability Resources/energy—gas or carbon tax Resources/energy—price Transportation choices/complexity	1 2 4 8 9 10 13 14 17	Climate change Economic growth Funding—amount Mobility—demand Mobility—capacity and access Mobility—expectation for mobility Resources/energy—supply Resources/energy—demand Road freight
4	Funding—amount	2 9 17 19 20 21	Economic growth Mobility—capacity and access Road freight Technology—physical and fixed Technology—IT Transportation choices/complexity		*None*

#	Cause (Driver)	#	Increases	#	Decreases
5	Funding—proportion private	4 21	Funding—amount Transportation choices/complexity	6 7	Government role—large/small Government role—federal/state/local
6	Government role—large/small	4 7 9 15 18 19 21	Funding—amount Government role—federal/state/local Mobility—capacity and access Resources/energy—gas or carbon tax Security Technology—physical and fixed Transportation choices/complexity	1 2 5	Climate change Economic growth Funding—proportion private
7	Government role—federal/state/local	4 6 9 18 19 21	Funding—amount Government role—large/small Mobility—capacity and access Security Technology—physical and fixed Transportation choices/complexity	1 2 5 15	Climate change Economic growth Funding—proportion private Resources/energy— gas or carbon tax
8	Mobility—demand	1 5 6 7 10 14 16 21	Climate change Funding— proportion private Government role—large/small Government role—federal/state/local Mobility—expectation for mobility Resources/energy—demand Resources/energy—price Transportation choices/complexity	3 12	Priority on environmental quality Public commitment to sustainability
9	Mobility—capacity and access	2 8 10 14 16	Economic growth Mobility—demand Mobility—expectations for mobility Resources/energy—demand Resources/energy—price	11	Population density
10	Mobility—expectations for mobility	1 5 6	Climate change Funding— proportion private Government role—	3 12	Priority on environmental quality Public commitment to

#	Cause (Driver)	#	Increases	#	Decreases
			large/small 7 Government role—federal/state/local 8 Mobility—demand 14 Resources/energy—demand 16 Resources/energy—price 21 Transportation choices/complexity		sustainability
11	Population density	2	Economic growth	8 10 14	Mobility—demand Mobility—expectations for mobility Resources/energy—demand
12	Public commitment to sustainability	3 6 7 11 15 16 21	Priority on environmental quality Government role—large/small Government role—federal/state/local Population density Resources/energy—gas or carbon tax Resources/energy—price Transportation choices/complexity	1 2 4 8 9 10 13 14	Climate change Economic growth Funding—amount Mobility—demand Mobility—capacity and access Mobility—expectation for mobility Resources/energy—supply Resources/energy—demand
13	Resources/energy—supply	1 2 6 21	Climate change Economic growth Government role—large/small Transportation choices/complexity	16	Resources/energy—price
14	Resources/energy—demand	16	Resources/energy—price		*None*
15	Resources/ energy—gas or carbon tax	4 6 7 11 16	Funding—amount Government role—large/small Government role—federal/state/local Population density Resources/energy—price	1 2 8 10 14 17	Climate change Economic growth Mobility—demand Mobility—expectation for mobility Resources/energy—demand Road freight

#	Cause (Driver)	#	Increases	#	Decreases
16	Resources/ energy—price	3 11 12 13 20	Priority on environmental quality Population density Public commitment to sustainability Resources/energy—supply Technology—IT	2 8 10 14 15 17	Economic growth Mobility—demand Mobility—expectations for mobility Resources/energy—demand Resources/energy—gas or carbon tax Road freight
17	Road freight	1 2	Climate change Economic growth		*None*
18	Security	2	Economic growth	4	Funding—amount
19	Technology—physical and fixed	2 9 21	Economic growth Mobility—capacity and access Transportation choices/complexity		*None*
20	Technology—IT	2 9 19 21	Economic growth Mobility—capacity and access Technology—physical and fixed Transportation choices/complexity	1 8 10 18	Climate change Mobility— demand Mobility— expectations for mobility Security
21	Transportation choices/ complexity	9	Mobility—capacity and access	11	Population density

Table 6.3. Correlation Matrix by Rows.

	1	2	3	4	5	6	8	9	11	13	14	15	13	17	18	19	20	21
1. Climate change	1.00	**0.32**	**−0.48**	0.00	**0.50**	**−0.17**	**0.40**	**−0.16**	**−0.43**	**0.35**	**0.51**	**−0.45**	**−0.28**	**0.35**	**−0.36**	**−0.20**	**0.22**	**−0.17**
2. Economic growth	**0.32**	1.00	**−0.37**	**−0.16**	0.00	**−0.52**	**0.37**	**0.41**	**−0.49**	**0.15**	**0.48**	**−0.51**	**−0.43**	**0.45**	**−0.07**	**0.19**	**−0.13**	**0.03**
3. Priority on environmental quality	**−0.48**	**−0.37**	1.00	**−0.19**	**−0.32**	**0.04**	**−0.35**	**0.04**	**0.37**	**−0.22**	**−0.66**	**0.33**	**0.03**	**−0.45**	**0.03**	**−0.20**	**0.05**	**−0.33**
4. Funding—amount	0.00	**−0.16**	**−0.19**	1.00	**−0.32**	**−0.04**	**0.18**	**0.35**	**−0.18**	**0.45**	**0.18**	**−0.05**	**−0.03**	**0.00**	**0.44**	**0.45**	**0.24**	**0.12**
5. Funding—proportion private	**0.50**	0.00	**−0.32**	**−0.32**	1.00	**0.33**	0.00	**−0.31**	0.00	0.00	**0.25**	**−0.45**	**0.28**	0.00	**−0.73**	**−0.40**	0.00	0.00
6. Government role—large/small	**−0.17**	**−0.52**	**0.04**	**−0.04**	**0.33**	1.00	**−0.33**	**−0.35**	**0.38**	**−0.47**	**−0.28**	**0.45**	**0.46**	**−0.24**	**−0.08**	**−0.18**	**−0.15**	**−0.07**
8. Mobility—demand	**0.40**	**0.37**	**−0.35**	**0.18**	0.00	**−0.33**	1.00	**0.21**	**−0.77**	**0.19**	**0.80**	**−0.20**	**0.17**	**0.57**	**0.02**	**0.26**	**0.04**	**0.08**
9. Mobility—capacity and access	**−0.16**	**0.41**	**0.04**	**0.35**	**−0.31**	**−0.35**	**0.21**	1.00	**−0.36**	**0.22**	**0.23**	**−0.19**	**−0.29**	**0.22**	**0.35**	**0.53**	**0.09**	**0.26**
11. Population density	**−0.43**	**−0.49**	**0.37**	**−0.18**	0.00	**0.38**	**−0.77**	**−0.36**	1.00	**−0.20**	**−0.73**	**0.26**	**0.16**	**−0.61**	0.00	**−0.23**	**0.00**	0.00
13. Resources/energy—supply	**0.35**	**0.15**	**−0.22**	**0.45**	0.00	**−0.47**	**0.19**	**0.22**	**−0.20**	1.00	**0.36**	**−0.63**	**−0.20**	0.00	0.00	**0.28**	**0.63**	0.00
14. Resources/energy—demand	**0.51**	**0.48**	**−0.66**	**0.18**	**0.25**	**−0.28**	**0.80**	**0.23**	**−0.73**	**0.36**	1.00	**−0.38**	**0.19**	**0.54**	**0.04**	**0.29**	**0.08**	**0.32**
15. Resources/energy—gas or carbon tax	**−0.45**	**−0.51**	**0.33**	**−0.05**	**−0.45**	**0.45**	**−0.20**	**−0.19**	**0.26**	**−0.63**	**−0.38**	1.00	**0.12**	0.00	**0.54**	**0.12**	**−0.20**	**0.20**
16. Resources/energy—price	**−0.28**	**−0.43**	**0.03**	**−0.03**	**0.28**	**0.46**	**0.17**	**−0.29**	**0.16**	**−0.20**	**0.19**	**0.12**	1.00	**−0.20**	**−0.07**	**−0.15**	**−0.12**	**0.12**
17. Road freight	**0.35**	**0.45**	**−0.45**	**0.00**	0.00	**−0.24**	**0.57**	**0.22**	**−0.61**	0.00	**0.54**	0.00	**−0.20**	1.00	0.00	**0.57**	**0.32**	**0.47**
18. Security	**−0.36**	**−0.07**	**0.03**	**0.44**	**−0.73**	**−0.08**	**0.02**	**0.35**	0.00	0.00	**0.04**	**0.54**	**−0.07**	0.00	1.00	**0.45**	**−0.11**	**0.27**
19. Technology—physical and fixed	**−0.20**	**0.19**	**−0.20**	**0.45**	**−0.40**	**−0.18**	**0.26**	**0.53**	**−0.23**	**0.28**	**0.29**	**0.12**	**−0.15**	**0.57**	**0.45**	1.00	**0.48**	**0.60**
20. Technology—IT	**0.22**	**−0.13**	**0.05**	**0.24**	0.00	**−0.15**	**0.04**	**0.09**	**0.00**	**0.63**	**0.08**	**−0.20**	**−0.12**	**0.32**	**−0.11**	**0.48**	1.00	**0.20**
21. Transportation choices/complexity	**−0.17**	**0.03**	**−0.33**	**0.12**	0.00	**−0.07**	**0.08**	**0.26**	0.00	0.00	**0.32**	**0.20**	**0.12**	**0.47**	**0.27**	**0.60**	**0.20**	1.00

Note: Bold black means greater than 0.30. Bold red means less than −0.30.

Finally, two types of factors are calculated—unrotated and varimax:

- In the first method, unrotated factors are orthogonal to each other, meaning that they are not correlated to each other. The five factors then represent a five-dimensional space in which each axis in the space is perpendicular to every other factor, much as a regular three-dimensional coordinate system is.
- In the second method, factors that are rotated using varimax rotation recognize that some factors might be correlated or, in other words, they are not perpendicular to each other.

The unrotated and varimax factors produce similar results so that neither is preferred; both are used in this study. The factor loadings for the unrotated and varimax rotated factors, along with a summary list of the variables that loaded high (more than 0.30) and low (less than −0.30), appear in Table 6.4.

Thus, the factor loadings reveal a relatively small number of clusters of variables that tend to move together. The uncertainties associated with those clusters of variables will then be used as the basis for the multi-driver scenarios.

Some of these factors make good sense since they load variables that would be expected to move together. Factor F1 in both rotations is an excellent portrayal of a return to business as usual, the transport sector as it existed 10 to 20 years ago. While that scenario is less likely today than it was at that time, the resolution of current economic and political problems could put the transportation sector back on the road to good health.

But high factor loadings do not necessarily mean that the variables themselves increase. They only mean that the variables tend to move together in whatever direction they do move. So the opposite scenario is also plausible, perhaps even more plausible than the first one—namely, that the government reasserts itself against the forces of the marketplace and introduces legislation to adequately fund the transportation sector through increased gas or carbon taxes and regulation to curb pollution and the emission of GHGs. Of course, that scenario is also similar to Factor F2 in both rotations. So the factor loadings show clusters of variables that would tend to move together, suggesting ways of integrating the various drivers into a few coherent scenarios.

Not all of the factors make such obvious sense, however. In fact, some seem contradictory. Unrotated Factor F4, for instance, includes high loadings for both the possibility of higher transportation taxes and increased road freight. Those do not seem to be variables that would move together. In the end, then, the analyst must still exercise some judgment about which factors can be used as the basis for plausible scenarios. The factors do not algorithmically result in scenario clusters, but they do suggest what those clusters could be.

A second analysis was conducted by treating the columns as variables and the rows as data. The row-wise analysis showed which variables impacted the other variables in a similar way. The column-wise analysis showed which variables were impacted by the other variables in the same way. The correlation matrix and factor loadings for the column-wise analysis are presented in tables 6.5 and 6.6.

Table 6.4. Factor Analysis by Row.

Factor Analysis by Row

How variables affect others

	Unrotated factors				
	F1	**F2**	**F3**	**F4**	**F5**
Proportion of variance	27%	15%	10%	10%	9%
Cumulative proportion of variance	27%	42%	52%	61%	70%
High	Climate change Economic growth Mobility—demand Mobility—capacity and access Resources/energy—supply Resources/energy—demand Road freight Technology—physical and fixed Technology—IT Transportation choices/complexity	Funding—amount Resources/energy—gas or carbon tax Security Technology—physical and fixed	Government role Resources/energy—price Technology—IT	Resources/energy—gas or carbon tax Road freight	Technology—physical and fixed Technology—IT
Low	Priority on environmental quality/public commitment to sustainability Government role Population density Resources/energy—gas or carbon tax	Climate change Funding—proportion private	Economic growth Mobility—capacity and access	Funding—amount Resources/energy—supply Technology—IT	Funding—proportion private Resources/energy—demand Resources/energy—price

	Rotated				
	F1	**F2**	**F3**	**F4**	**F5**
	21%	14%	13%	12%	10%
	21%	36%	48%	60%	70%
High	Climate change Economic growth Mobility—demand capacity and access Resources/energy—demand Road freight	Funding—amount Mobility—capacity and access Resources/energy—gas/carbon tax Security Technology—physical and fixed	Funding—proportion private Government role Resources/energy—price	Funding—amount Resources/energy—supply Technology—IT	Resources/energy—gas or carbon tax Mobility—physical and fixed Technology—IT Transportation choices/ complexity
Low	Priority on environmental quality/public commitment to sustainability Population density Resources/energy—gas/carbon tax	Climate change Funding—proportion private	Economic growth Mobility—capacity and access	Resources/energy—gas or carbon tax	

Table 6.5. Correlation Analysis by Columns.

	1	2	3	4	5	6	8	9	11	13	14	15	13	17	18	19	20	21
1. Climate change	**1.00**	**−0.43**	**0.59**	−0.20	−0.29	0.15	−0.17	**−0.38**	0.00	**−0.41**	0.00	**0.41**	0.29	**−0.31**	−0.29	−0.26	−0.19	0.00
2. Economic growth	**−0.43**	**1.00**	**−0.43**	0.29	0.25	0.06	**0.30**	**0.30**	−0.22	**0.35**	0.06	**−0.42**	**−0.37**	0.06	−0.25	−0.04	−0.03	0.25
3. Priority on environmental quality	**0.59**	**−0.43**	**1.00**	−0.05	0.00	0.16	0.19	**−0.37**	−0.03	**−0.44**	0.05	**0.57**	**0.31**	**−0.39**	0.00	−0.12	0.05	**−0.41**
4. Funding—amount	−0.20	0.29	−0.05	**1.00**	**0.35**	**0.31**	−0.14	0.00	**0.43**	0.25	−0.25	−0.28	−0.18	0.13	**0.35**	**0.63**	**0.71**	**0.35**
5. Funding—proportion private	−0.29	0.25	0.00	**0.35**	**1.00**	0.27	0.00	0.00	0.00	0.00	0.00	−0.24	0.00	0.00	0.00	**0.45**	**0.33**	0.00
6. Government role—large/small	0.15	0.06	0.16	**0.31**	0.27	**1.00**	**−0.33**	−0.12	0.09	−0.19	−0.13	0.28	0.00	**−0.41**	−0.27	**0.32**	**0.59**	0.27
8. Mobility—demand	−0.17	**0.30**	0.19	−0.14	0.00	**−0.33**	**1.00**	0.23	**−0.31**	0.21	0.14	0.04	−0.30	0.14	0.00	0.04	−0.17	0.00
9. Mobility—capacity and access	**−0.38**	**0.30**	**−0.37**	0.00	0.00	−0.12	0.23	**1.00**	**−0.40**	0.00	**0.59**	**−0.45**	**−0.67**	0.24	**0.33**	0.15	0.11	**0.33**
11. Population density	0.00	−0.22	−0.03	**0.43**	0.00	0.09	**−0.31**	**−0.40**	**1.00**	**0.51**	**−0.69**	−0.02	0.18	**0.47**	**0.36**	**0.43**	**0.32**	0.00
13. Resources/energy—supply	**−0.41**	**0.35**	**−0.44**	0.25	0.00	−0.19	0.21	0.00	**0.51**	**1.00**	**−0.38**	**−0.50**	**−0.35**	**0.75**	**0.35**	**0.32**	0.00	0.00
14. Resources/energy—demand	0.00	0.06	0.05	−0.25	0.00	−0.13	0.14	**0.59**	**−0.69**	**−0.38**	**1.00**	0.03	−0.27	−0.13	0.00	−0.16	−0.12	0.00
15. Resources/energy—gas or carbon tax	**0.41**	**−0.42**	**0.57**	−0.28	−0.24	0.28	0.04	**−0.45**	−0.02	**−0.50**	0.03	**1.00**	**0.59**	**−0.47**	**−0.47**	−0.18	0.03	−0.24
16. Resources/energy—price	0.29	**−0.37**	**0.31**	−0.18	0.00	0.00	−0.30	**−0.67**	0.18	**−0.35**	−0.27	**0.59**	**1.00**	−0.27	−0.25	−0.22	−0.17	−0.25
17. Road freight	**−0.31**	0.06	**−0.39**	0.13	0.00	**−0.41**	0.14	0.24	**0.47**	**0.75**	−0.13	**−0.47**	−0.27	**1.00**	**0.53**	**0.32**	−0.12	0.00
18. Security	−0.29	−0.25	0.00	**0.35**	0.00	−0.27	0.00	**0.33**	**0.36**	**0.35**	0.00	**−0.47**	−0.25	**0.53**	**1.00**	**0.45**	**0.33**	0.00
19. Technology—physical and fixed	−0.26	−0.04	−0.12	**0.63**	**0.45**	**0.32**	0.04	0.15	**0.43**	**0.32**	−0.16	−0.18	−0.22	**0.32**	**0.45**	**1.00**	**0.75**	**0.45**
20. Technology—IT	−0.19	−0.03	0.05	**0.71**	**0.33**	**0.59**	−0.17	0.11	**0.32**	0.00	−0.12	0.03	−0.17	−0.12	**0.33**	**0.75**	**1.00**	**0.33**
21. Transportation choices/complexity	0.00	0.25	**−0.41**	**0.35**	0.00	0.27	0.00	**0.33**	0.00	0.00	0.00	−0.24	−0.25	0.00	0.00	**0.45**	**0.33**	**1.00**

Note: Bold black means greater than 0.30. Bold red means less than −0.30.

Table 6.6. Factor Analysis by Columns.

Factor analysis by columns

How variables are affected by others

	Unrotated factors				
	F1	**F2**	**F3**	**F4**	**F5**
Proportion of variance	18%	17%	13%	12%	8%
Cumulative proportion of variance	18%	35%	48%	60%	68%
High	Population density Resources/energy—supply Road freight Security Technology—physical and fixed	Economic growth Funding—amount Funding—proportion private Government role Technology—physical and fixed Technology—IT Transportation choices/complexity	Population density	Economic growth Mobility—demand	Mobility—demand Security Technology—physical and fixed Technology—IT
Low	Climate change Priority on environmental quality/public commitment to sustainability Government role Resources/energy—demand Resources/energy—gas or carbon tax	Climate change Priority on environmental quality/public commitment to sustainability	Mobility—capacity Resources/energy—demand Security	Climate change	Economic growth

	Rotated				
	F1	**F2**	**F3**	**F4**	F5
	19%	16%	14%	11%	8%
	19%	35%	49%	60%	68%
High	Economic growth Mobility—capacity Resources/energy—supply Road freight	Funding—amount Funding—proportion private Government role Technology—physical and fixed Technology—IT Transportation choices/complexity	Population density	Population density Road freight Security Technology—physical and fixed Technology—IT	Economic growth Mobility—demand
Low	Climate change Priority on environmental quality/public commitment to sustainability Resources/energy—gas/carbon tax Resources/energy—price		Mobility capacity Resources/energy—demand Security	Economic growth	

Many of the same factors appeared in both analyses, and those will be used as the basis of the scenarios developed. In the end, the researchers judged that the factors presented a coherent set of variables that could be used as the basis for scenarios that integrated many drivers into the same future. Table 6.7 presents the major scenarios that resulted and the factors that suggested them.

As suggested by the scenario planning methodology, the futurist created titles for the scenarios. He derived the titles from both the drivers and the scenario narratives. Titles are extremely important in the construction of scenarios because they act as a shorthand or unique identifier of a specific scenario. In addition, the scenario kernel provides a short description of the entire scenario. The multi-driver scenarios are written as historical descriptions or future histories, also an approach common to the scenario planning methodology.

Table 6.7. Summary of Six Multi-driver Scenarios.

Scenario	Factors*	Key Drivers	Scenario Kernel
Back to the Future	R U F1 R V F1 C U F2 C V F1	High economic growth High transport use High resource use High technology development	The economy returns to health, and transportation has the technology and resources to grow again.
Government Redux	R U F2	High transport funding through new taxes and user fees More highway technology	The government reasserts itself as the primary driver of transportation in the United States and develops the funding resources to do so.
Bits over Buses	R U F3 R V F4	Private funding Government role centralized High gas prices High IT	A higher than expected increase in crude oil prices reduces the ability of ordinary people to travel as much as they used to. They turn instead to an expanded Internet, not only for communication but for most work and leisure activities that used to require physical movement.
Many Ways to Go	R V F5 C U F2 C R F2	Economic growth Funding amount Private funding Centralized government role Gas/carbon taxes and user fees High technology development Multimodal approaches	The government seeks new revenue in gas and carbon taxes and user fees, but rather than investing in the existing transportation system, it puts its money into new transport and information technology. This leads to a complex but efficient transportation system that includes significant shares of many different modes.
Escape to the Center	C U F3 C R F3	High population density Low mobility capacity Low security	The lack of mobility and increased threats to their well-being drive people out of the suburbs and into the city, reducing the demand for traditional highway transportation—the arrival of the vision for the advocates of smart growth.
Meltdown	R U F1 R V F1 C U F1 C V F1	Climate change Environmental quality/sustainability Gas/carbon tax Government role Population density	The pessimistic scenarios for climate change ended up being more accurate than the optimistic ones. As a result, the most important priority for the next few decades is struggling with nature rather than growing the economy.

* Key: R = row-wise analysis; C = column-wise analysis; U = unrotated factors; V = varimax rotated factors; F = the factor number in each set.

MULTI-DRIVER SCENARIOS

Scenarios are vehicles used to depict plausible long-term futures in a vivid and engaging manner. They are not intended to be single-point predictions. A scenario's portrait of the future may or may not actually occur, but that is not the point. Rather, the scenario contains and communicates the long-term implications of major trends and plans going on today, with a number of key assumptions and uncertainties that are currently unresolved and that would create substantially different futures depending on how they are resolved.

Scenarios may be presented as simple analytical descriptions of these alternative futures. More often, however, they are presented in other forms such as stories, historical descriptions or future histories, illustrations, and videos to communicate the *feel* of that future rather than just its intellectual content. The purpose is to make the future real, that is, for the target audience to realize that this scenario is one of their possible futures and that they might actually live and work in that future. And then, of course, they can think about what they should be doing today to prepare—not for *the* future, but for one of many plausible futures.

The research team created the multi-driver scenarios based on the clusters of drivers that emerged from the factor analysis of the cross-impact matrix. The six scenarios are described using historical descriptions or future histories. Future histories are retrospective accounts of how the future has developed. They are written in past tense, looking back to the future so they can be a retrospective report or news feature that describes how the future has developed up to that point (note that these scenarios do not follow a technical writing style). Thus, they provide a broad context in which to view the future. Each scenario incorporates a short section that provides insights into the potential implications of the scenario on the future of transportation. The six integrated scenarios, involving a number of drivers, will serve as a platform to frame and illuminate plausible long-term futures for the six transportation areas and the focus groups in Phase II. The following sections discuss these scenarios.

Back to the Future

Table 6.8 shows the key elements for this scenario.

Table 6.8. Key Scenario Elements for Back to the Future.

Scenario	Factors*	Key Drivers	Scenario Kernel
Back to the Future	R U F1 R V F1 C U F2 C V F1	High economic growth High transport use High resource use High technology development	The economy returns to health, and transportation has the technology and resources to grow again.

Key: R = row-wise analysis; C = column-wise analysis; U = unrotated factors; V = varimax rotated factors; F = the factor number in each set.

An Economic Trigger

The economy has finally turned around and is producing jobs the way it used to, but this time in a more sustainable way. Growth in the late 20th century had many of the same characteristics as growth the late 19th century—essentially boom and bust. The 1970s started the cycle, and it was

repeated five times into the 2010s. First it was oil shocks and stagflation—high inflation with low growth. The 20-times increase in the price of oil in 1980 would have astounded oil experts in 1970, yet it fueled a high-growth (and highly inflationary) economy as the government poured money in the economy to offset the ripple effects of high gas prices. But the bust came right after that, one of the worst recessions in the 20th century, intentionally created to wring inflation out of the economy. Intentionally or not, people still lost their jobs and their savings. The bust of 1987 was fueled by loose money again, this time due to the deregulation of the savings and loan industry. They were making sky-high profits by taking sky-high risks, even though their deposits were still insured by the Federal Deposit Insurance Corporation (FDIC). A 500-point loss in October 1987 showed that the system was unsustainable with another hard landing. The recession of 2001 and 2002 followed a period of irrational investment in Internet companies that had no profits or even revenue to speak of and no plans to get any except hope. The Great Recession of 2007 and 2008 was fueled by debt rather than sustainable demand. The only way to produce economic growth with incomes stagnant for most people was to grow consumption by growing debt. Deregulation led to overleveraged bets in the financial industry that also contributed to the collapse, requiring another—and much more expensive—government bailout. And finally, those bailouts lay the foundation for another Great Recession in 2014 and 2016. We thought they only came about once every 70 years. First Europe, then Japan, and finally the United States pulled the banking systems of the world down around their heads as they were unable to service their enormous debts.

And thus a giant rethinking began. The value of the economy was always measured in growth. The more money and the more goods and services purchased, the higher the standard of living and the presumed increase in happiness and well-being. But what was originally "You can never be too rich" soon became "Enough is enough," the phrase for the new era. People and even businesses were sick and tired of the boom and bust cycle. While the booms were fun, the busts were not. People finally realized that they were not that much better off at the end of the cycle than they were at the beginning. Then why all the pain of the cycle? What was the point? The aging boomers wanted more steady and predictable growth as well, so they got their representatives to put a second mandate on the Federal Reserve—to control growth and reduce risk. Just as the inflation of the 1970s convinced the Federal Reserve that keeping inflation in check was their primary mission, now they had two missions. They also had to keep growth in check. But what heresy. Everyone agreed that inflation beyond a low level was bad, but everyone also agreed that as much growth as possible was good. But now they changed their minds. Sustainable growth, somewhere around 2.5 percent per year, was the new target—not less but also not much more. The Federal Reserve had always had the tools necessary to cool growth when it got above 3 percent. They just never had the mandate to use them to control growth. After 20 years, however, with nary a recession in sight, the economy was booming by historical standards, though it never raced ahead as it had before only to come to a screeching halt with all the subsequent pain and recrimination. "Enough is enough" now meant just enough growth to keep the economy improving, but not so much that it got out of hand.

A Technological Trigger

People said it was like the beginning of the industrial revolution all over again. Of course, that was an exaggeration, but it felt pretty good anyway. A convergence of technologies in the 2010s

and 2020s had cured most of the ills that the economy suffered in the first decade. Rarely do technological breakthroughs live up to their promise as well as these have:

- Nanotechnology far outstripped even its most optimistic advocates. Water desalination, heat-reflective coatings, lighter and stronger metals, and ultra-high-storage batteries all became possible thanks to the manipulation of matter at the atomic level. Traditional manufacturing seemed crude by comparison. Given their experience with manufacturing, the old Midwestern Rust Belt emerged as the new Polymer Belt that brought advanced manufacturing jobs back to America.
- Biotechnology, another micro-technology, has begun to actually lower the cost of health care by keeping people healthier longer and treating them more effectively when they do get sick. A completely unexpected spinoff of this new bio-inspired age was how we could apply what we had learned about biological organisms to human organizations (human organisms) as well. Overhead rates dropped, and teams became much more effective once they were allowed to self-organize around a task.
- Japan led the world in the application of robotics to almost every physical task. Robots had populated factories for years, but now they were taking over the service industries as well by cooking, cleaning, and moving all manner of things around the factory, office, hospital, and even home. The Japanese were even working on robot freight haulers given their incredibly small workforce compared to the size of their economy.
- Of course, information technology still had a lot to offer through ubiquitous sensor networks, voice recognition, natural language processing, huge databases, and apparently intelligent responses and actions to most queries or commands. Intelligent "assistants," first pioneered by IBM's Watson and Apple's Siri, were taking over many of the tasks that had occupied much of people's time in the old work-oriented environment.
- And, finally, the new miniature technologies had reduced society's demands on the environment, but it had not eliminated the threat of resource scarcity or climate change. Nanotechnologies consumed less bulk material than older chemical processes did because it produced less waste. And biotechnology was actually creating energy, turning sunlight into hydrocarbons in large algae farms fueled by carbon dioxide from coal plants and saltwater from coastal areas. The cost, however, was the new threat that nano- or bio-materials in the natural environment would alter species or even affect humans in subtle but significant ways.

Nevertheless, the growth in productivity was truly large by historical standards, if it were not for one problem—people were being squeezed out of the workplace with machines doing all the work. The unemployment rate never recovered from the 2007 and 2008 recession. In fact the rate today would be between 20 percent and 25 percent had we kept measuring it that way. But the Bureau of Labor Statistics gave that up years ago because "work" had become optional. With so much abundance and prices lower than ever, it was simply easier to support people on a small public stipend than to continually flog the economy into producing more jobs. People still worked, but more on something they wanted to do or thought that someone else could use. The Maker culture that emerged in the 2000s became a way of life for many. Home-grown nano- and bio-hacks were now more common than large industrial firms. The term for the new economy was WikiWorld, a huge open-source collaboration that seemed impossible given the economic and psychological theories of the 19th and 20th centuries.

But magic bullets still cause damage as they ripple through society. Not everyone embraced the new normal. In particular, the work ethic took a big hit, making many people feeling useless and left behind. They needed the discipline of having to make a living to get them out of bed in the morning. The disorientation from reorganizing the very fabric of work fueled rising rates of depression and crime. A new generation waking up in this world would accept it as normal, if not inevitable, so the dislocation was mostly confined to the transition generation.

A Cultural Trigger

"Nothing succeeds like failure," and the Millennials had plenty of that. Their Baby Boom parents and grandparents had left the world in quite a mess—high unemployment, high education debt, unsustainable government deficits, increasing global temperatures, and apparently no way to succeed on a regular basis. The American Dream had become the American Nightmare. The Baby Boom invented the Me Generation in the 1980s and pushed it as hard as they could until they retired and eventually died in the second quarter of the century. But just as the Depression and WWII generation (called the Greatest Generation in a popular book in the 1990s) had laid the foundation for American prosperity in the second half of the 20th century, so the Millennials and their descendants began fixing the problems in the first third of the 21st century. They first realized that while many had been brought up in relative security and prosperity, long-term security and prosperity had to be earned, not assumed. Entitlements were out; hard work was the *new black*. You get what you produce in this world, not just what you want. Secondly, they balanced individual interests with community interests. They resurrected long-dormant values of service, responsibility, and sacrifice. They took care of each other as they took care of themselves. "Do unto others…" was popular again, an astounding revival from the days of Gordon Gekko when greed was good. In fact, greed had become unfashionable and mildly distasteful to most. Along with a healthy dose of creativity and ingenuity, the United States was again the leading economy in the world; and this time, not only in services like finance and entertainment, but also in technology and manufacturing around the world. They had experienced the searing pain of the first two decades of their century just as their great-grandparents had in theirs, and they turned out much better for it.

Potential Implications for Transportation

The Back to the Future scenario has the following implications for transportation:

- Demand for mobility is consistent with the level of infrastructure development.
- Focus shifts to self-sustenance with investments in breakthrough technology to support clean water, super foods, and medical technologies. Expansion of the network progresses at a moderate pace in keeping with sustainability principles.
- Private-sector development of new technologies allows data generated from vehicles and roadside to contribute to smart, interactive, and real-time trip planning, and to provide for balancing of system loads.
- Funding is generated by fuel tax primarily and is declining, but is less of a crisis and crippling problem because demand is reduced through:

- Higher density development: Demand is more dispersed than concentrated, and people are committed to principles of sustainability in urban land form.
- Technology advancements: Technology provides alternatives to traditional travel modes, including increased use of telecommuting and home-based work.

Government Redux

Table 6.9 shows the key elements for this scenario.

Table 6.9. Key Scenario Elements for Government Redux.

Scenario	Factors*	Key Drivers	Scenario Kernel
Government Redux	R U F2	High transport funding through new taxes More highway technology	The government reasserts itself as the primary driver of transportation in the United States and develops the funding resources to do so.

* Key: R = row-wise analysis; C = column-wise analysis; U = unrotated factors; V = varimax rotated factors; F = the factor number in each set.

Few things mimic a pendulum more than the public mood. As a result, governance in the modern world behaved just like a pendulum. Having discovered the magic of fossil fuel, division of labor, and return on capital investment, societies initially endowed merchants with extraordinary power and scope. First in the British Isles and the European Continent, then to the British colonies and to Japan, and now operating throughout the world, the captains of industry pushed their advantage to the hilt. Capitalism is about capital: "Them that has gets." The rich get richer, and the poor get welfare. In the United States, the 1890s were called the Gilded Age when the trusts, controlled by a few ultra-wealthy individuals, ran the country. In Japan, they were *Keiretsu*; in Korea, *Chaebol.*

But a strange thing happened at the end of the 19th century in Europe, around the beginning of the 20th century in the United States and later elsewhere. Most people did not like the kind of society that the Trusts created. They were poor, worked in dangerous jobs, and enjoyed few if any rights. Even children were subjected to the discipline of the workplace, so they limited the Trusts through government action. First it was the Progressive Movement in the 1910s, the New Deal in the 1930s, and finally, the Great Society in the 1960s. From 1900 to 1965, government was good, and the market, which they believed produced mostly economic misery including the Great Depression, could not be trusted.

But the pendulum started swinging back at the height of the Great Society, as pendulums are wont to do. First in the U.K., Margaret Thatcher adopted the economics of Frederick Hayek, and Ronald Regan followed suit with the supply-side economics of Milton Friedman. Government was now bad, the source of all trouble, and the market was good. Let's run things like a business, not like overpaid bureaucrats. Over the decades, that philosophy produced the savings and loan crisis of the 1980s, the tech bubble of the 1990s and the Great Recession of the 2000s. It was a mini-Gilded Age all over again.

And the pendulum started swinging again, of course, in the opposite direction. A full-scale reformist movement arose from the splinter groups like the Tea Party, Occupy Wall Street, and a

host of other popular uprisings. People were angry; when angry enough, they usually get what they want.

The electoral system had been hijacked by the two political parties so that almost all legislative representatives ran in “safe” districts. That meant that winning the primary was tantamount to winning the election, and winning the primary required securing the support of the base, the most extreme members of the party. When elected, therefore, those representatives had to represent the people who elected them—not all or even a majority of the voters in their district, but rather the minority of party extremists. As a result, politics became an extended game of chicken—who would blink first, rather than an attempt to achieve reasonable actions on pressing issues. The reform was first to mandate that districts be drawn by expert panels rather than state legislators. Some states even adopted an algorithm that produced even more geographically contiguous and balanced districts than the panels did. Moderation reined in Congress and in state legislature for the first time in decades.

The system of governance had also been hijacked by special interests who stormed Congress with the relentless pursuit of their goals. Backed by the enormous financial resources required to be elected in the 2010s, the lobbyists pressed their case on the hapless representatives. And woe to legislator who stepped out of line. The reform in this case was twofold:

- To eliminate private money from elections through public funding.
- To limit the time for campaigning to four months before an election.

As a result, the influence of special interests was severely reduce, and the legal representatives had more time to actually govern since they were not running for office and raising money all the time.

A final reform was a new type of balanced-budget constitutional amendment. The two economic theories of the 20th century that took an explicit position on the role of government in society were the mixed economy of John Maynard Keynes and the free-market economy of Milton Friedman. Either one may have worked by itself, but politicians tended to practice them one at a time. They used free-market, supply-side theories in times of prosperity, and they resorted to government bailouts in times of distress. The Second Great Recession (the Sovereign Debt Recession) of 2014 through 2016 was the result of government guaranteeing the bad debts of the banks and financial institutions in 2007 and 2008 without having the resources do so. Had they been running budget surpluses during the good times, they would have had the resources to aid the ailing economy, but they did not. The reform in this case was a new form of Balanced Budget Amendment to the Constitution, finally adopted in 2021. Rather than balancing the federal budget every year, the way many states have to, the amendment offers more flexibility to save and to spend depending on the conditions of the economy. It restricts government spending to a fixed percent of the national economy, except during times of war. It requires that the budget be balanced over a five-year period, not every year, and it requires that the government run a surplus in two of those five years. While the federal debt is still enormous, at least the government may not be adding to it anymore with deficits each year for decades.

The result was some restrictions on some freedoms, such as redistricting, lobbying, and spending, but the benefit was a democracy that elected the right people and gave them the time, incentive, and means to see to the country's needs to the best of their ability.

Potential Implications for Transportation

The Government Redux scenario has the following implications for transportation in the pre-reform period:

- Funding limitations up to 2020 lead to further deterioration of the system and growing congestion unable to be addressed by system expansion.
- States seek innovative ways to deal with their most pressing transportation issues but are able to gain only enough public support to maintain the system at a minimal level.
- The situation is also complicated by high levels of state borrowing in the period between 2005 and 2015, precipitating further decline in service level in the absence of new revenue sources.

The scenario has the following implications for transportation in the post-reform period:

- With increased public trust, the door is open to federal leadership in significant expansion of tolling to the interstate system and ultimately to full network pricing.
- The initial motivation is the generation of sustainable revenue sources, but the incremental application of tolling across the system serves a demand management function in congested areas through variable pricing, thus reducing significant infrastructure expansion to meet demand.
- A new sustainable revenue source is available to invest in transit and alternative modes and support strategic capacity expansion for freight and alternative freight modes.
- Leading-edge vehicle technologies improve safety and reduce vehicle headway so that the system can be more efficiently operated.
- Privately administered payment mechanisms allow drivers to pay for road user fees while also paying for other services such as premium toll facilities, parking, navigation and location assistance with real-time traffic conditions, and pay-as-you-drive car insurance.

Bits over Buses

Table 6.10 shows the key elements for this scenario.

Table 6.10. Key Scenario Elements for Bits over Buses.

Scenario	Factors*	Key Drivers	Scenario Kernel
Bits over Buses	R U F3 R V F4	Private funding Government role centralized High gas prices High IT	A higher than expected increase in crude oil prices reduces the ability of ordinary people to travel as much as they used to. They turn instead to an expanded Internet, not only for communication but for most work and leisure activities that used to require physical movement.

* Key: R = row-wise analysis; C = column-wise analysis; U = unrotated factors; V = varimax rotated factors; F = the factor number in each set.

Peak oil production had been discussed for decades, and now it was here. We were not running out of oil exactly, but we were running low on the cheap, easy stuff, at least. And then there was the Mideast war of 2016, in which Iran attacked Saudi oil facilities and the Saudis responded in kind, which jumped the price of oil to over $400 a barrel.[25] The sudden jump reminded people of the 1970s—rationing, price controls, and long lines, but most of all the inability to drive anywhere you wanted because the price was simply too high. Wrenching the automobile from the fabric of American life was not just difficult; it was disastrous. People began the Post-War Era in love with their cars and all they stood for—mobility, freedom, and status. As a result, they approved the Interstate Highway System, the largest public-works project in history that had cost $1.5 trillion by 1991,[26] 90 percent of which was funded by the federal government. And now the utility and the status of the American automobile were under pressure. They might be electric someday, but the infrastructure for electrifying and maintaining the fleet was not in place and would not be for a decade or more. Biofuels were still in their infancy as were fuel cells. No, the American public would have to do without their vehicles for the time being.

So what did they do? They jumped on the Internet for a solution. Not just to *search* for a solution but to actually use the Internet as *the* solution. Futurists had been talking about the Information Society for a long time, since Daniel Bell's *Commission on the Year 2000* and Alvin Toffler's *Future Shock* and *Third Wave* in the 1960s and '70s. Much progress had been made. The Internet had already transformed every institution in society, even schools eventually, but it was used along with physical mobility, not instead of it. Now it really had to perform. Modern society would become a true Information Society as it had become a true Automobile Society in the 1950s and '60s.

The first and easiest fix was for people to work from home rather than in the office. Almost 70 percent of households had broadband access by this time, and many people were already accessing their servers from home in the evenings and on the weekends. Smartphones had made remote access as common as, well, the automobile. So replacing physical with virtual presence in the office was not a technical problem, but it was a huge behavioral adjustment. Everyone from managers to teachers to health professionals to sales people were still used to doing most of their business face-to-face. And everyone still said that face-to-face was the best way to do business, but it was just too expensive except for the most critical interactions. So they had to learn to work together and be evaluated on outcomes rather than activities. Contract work took the place of full-time employment. People worked on their own time in their own way, and job satisfaction soared, particularly for those not spending the hours in traffic jams five days a week.

But not everyone had participated in the knowledge economy before the shock, and not everyone would do so afterwards. How many would be left out? And what would they do? It turned out better than the pessimists thought, but, of course, not as good as the optimists hoped. First of all, the education system had not prepared people for independent, self-managed work, so many struggled. The education system adjusted, literally by preparing people to work online by teaching them online. Still a sizable proportion of the population was not technically or emotionally fit to work this way. But what would they do in a society without easy access to transportation? The answer was staring us right in the face. Manual work still needed to be done—building, painting, fixing, and maintaining. The difference was that a few people in the neighborhood were good at that, so they became local contractors to the stay-at-home workforce. It was not a prosperous life, but it did earn the fixers, as they were called, a certain local respect because their skills improved as time went on.

Another big adjustment was commerce and trade. The cost of transportation in the Oil Era was a single-digit percent of the total cost of goods to the consumer. Hence, it paid to manufacture overseas, reaping a large decrease in labor cost for a modest increase in transportation cost. But that equation was now upside down. Buying local had been a mantra of the progressive class for a long time. Now business had to take up the refrain. Very low-volume manufacturing based on new materials helped, as did low-maintenance crops from the biotech sector for low-volume farmers. Of course, the ultimate in local was in the home, but that is not far off now with desktop manufacturing and urban farming both gaining ground.

After a while and with great reluctance, a person's enhanced capabilities and skills with remote communication changed personal relations as well. Families living across the country, initially separated by high gas prices, eventually moved closer together. You could work just as easily from Cleveland as from the suburbs. Parents were home with their children; neighbors became friends (and enemies!) again; folks used the new tools and sites for entertainment and even virtual travel. It was the rural village all over again, but this time connected to the world.

And since people were not driving anymore, revenues from the gas tax plummeted so much that the concept of the Highway Trust Fund was laughable. But that is where the private sector stepped in. Some transportation was still necessary, and business saw an investment opportunity there. Privately operated toll roads, of course, had experienced an on-and-off-again history. But that was easy to put back into place. With the cost of gasoline sky high, a few more dollars to get to your destination was not such a big deal, as long as you did not have to do it too often. The traffic was light, but then so were the maintenance costs on existing highways and toll roads. The real problem was streets and thoroughfares. You could not exactly toll the street in front of your house. But business got together and, with the blessing of state and city governments, created transportation cooperatives based on neighborhoods, similar to management districts that had been set up in the 1990s. The residents of an area would pay a flat fee to a private contractor to maintain the streets in that area at some level of performance, which was precisely specified. The higher the level, the higher the fee. However, residents in some areas chose not to set up the cooperative, or they could not afford the fee to do so. So roads in those areas had to be closed for lack of maintenance; that was considered a huge social problem at the outset, but even that turned out better than planners expected. The neighbors, through their own labor and with the help of the fixers, turned some streets into lanes for all manner of human-powered vehicles. The overall health of those populations even improved with exercise and with the inability to order

takeout anymore. Local gardens flourished, and people returned to a more rural lifestyle even in the big cities. The system was called “pay as you go,” so not owning an automobile became a real option for homeowners.

Potential Implications for Transportation

The Bits over Buses scenario has the following implications for transportation:

- The reduction in driving resulting from fuel prices leads to reductions in demand on the transportation system. Without revenues from the fuel tax that produce the resources for system expansion, available revenue levels dictate a focus on maintenance and preservation rather than expansion. Maintenance is supported by toll revenue on highways.
- Telecommuting and home-based work resulting from contract labor rather than traditional employment, in combination with fuel prices, leads to significant reductions in peak-period demand on the system.
- State DOTs turn over roads with local-access functionality to transportation cooperatives for maintenance and preservation.

Many Ways to Go

Table 6.11 shows the key elements for this scenario.

Table 6.11. Key Scenario Elements for Many Ways to Go.

Scenario	Factors*	Key Drivers	Scenario Kernel
Many Ways to Go	R V F5 C U F2 C V F2	Economic growth Funding amount Private funding Centralized government role Gas/carbon taxes High technology development Multimodal approaches	The government seeks new revenue in gas and carbon taxes, but rather than investing in the existing transportation system, it puts its money into new transport and information technology. This leads to a complex but efficient transportation system that includes significant shares of many different modes.

* Key: R = row-wise analysis; C = column-wise analysis; U = unrotated factors; V = varimax rotated factors; F = the factor number in each set.

The Oil Era and hence the Automobile Era were over, for the time being at least, until a new transportation alternative could be found. Would it be the electric-, biofuel-, or fuel-cell-powered car that could use the existing road system? Or perhaps no cars at all, with the Internet as the highway of the future, as so many had dubbed it already. At least, the steep carbon tax made one of those much more likely before a return to the internal combustion engine, if ever.

The decision depended on the need for humans to have face-to-face interaction. The high-tech enthusiasts said that virtual interaction was just as good as face-to-face once you got the hang of it. Others disagreed. Social scientists arrayed themselves on all sides of the question, saying:

- People would get claustrophobic with such a small circle of face-to-face contacts.
- Aside from being a boon, parents at home with their children all day might actually narrow or even stifle their interpersonal growth.
- Neighbors who had enough face-to-face contact at work could easily avoid each other at home, but now they would crave the contact, even if it led to more neighborly conflict.
- The looser ties between employer and employee, between manager and worker, would lead to listlessness, lack of loyalty, and a churning labor force.

All of these arguments from psychologists, sociologists, teachers, and mental-health professionals convinced the business community in one medium-sized city to establish a unique private-public corporation called Ways to Go (WTG). WTG would invest in an ambitious experiment with an outrageous goal—to provide as much mobility to their residents as they had before, but without the automobile. (Earlier partnerships like this were called public-private partnerships, but this one was *private-public* because government was the minority partner here.) WTG could not bring the automobile back, at least not right away. And rather than try, it focused its talent and resources on a truly 21st century transportation system. That system would provide the same VMT (vehicle miles *traveled*, not driven) at the same average speed and at comparable cost as the automobile had done when gasoline was $5 a gallon in 2017, but with less than 10 percent of the automobile miles as before. If the experiment succeeded, the investors would have a world market in designing and building similar multimodal transportation systems elsewhere.

It was expensive to drive these days because the higher fuel prices had been made even higher with a $40-per-ton carbon tax. Still many people were determined to drive. They had grown up in a world of autos, and they could not imagine life without them. So to get the automobiles off the road, WTG convinced the city and county to close many roads since they did not have the money to maintain them anyway. They imposed real-time congestion fees on those that stayed open and taxes to enter and drive in certain parts of the city, like what London did in the early 2000s. As a result, vehicle miles driven (VMD) went down to 7 percent of the level from 10 years before.

But that was the easy part. The promise was that people would travel the same amount with just as much convenience. And if people fell in love the WTG system, it could become a tourist attraction and the basis for a new economic cluster of advanced transportation systems.

WTG and city leaders sold the vision to the voters, who approved it by a fairly wide margin. So it was time to get to work. Money would come from:

- Private investment, which retained the rights to patents and trademarks on the new systems.
- A portion of the federal carbon tax that was set aside for innovative transportation systems.
- The new toll and congestion fees imposed by the city and county.

- Investments from large corporations like UPS for logistics, Siemens for advanced transportation technology, and Disney for people moving and entertainment.

People were excited. So what was the plan? The outcomes had already been set. What were the strategies?

- Obviously all modes of transportation would be considered, even some specialty automobiles.
- All modes would have to be operationally solvent. WTG would design, build, and operate the system. WTG would receive no public funds for operations, however, so the system had to have a good chance of at least breaking even on an operating basis.
- The nodes considered were:

    - **Trains:** Trains were employed sparingly and only between highly trafficked routes. Trains had become a showcase for a number of cities in the 1990s and through the 2020s, but most required huge subsidies to run. It was even possible that there would be no trains.
    - **Buses:** Buses would be the backbone of the public portion of the systems, but not buses like the population were used to. Traditionally, buses and most trains never paid for themselves because they competed with more convenient and comfortable automobiles. So they were used only by the bottom quarter of the population, people who could not afford an automobile. Now 80 percent of the population could not afford an automobile, so much of the stigma of traveling by bus was going away. Nevertheless, WTG launched a public-relations campaign to make bus riding more interesting, enjoyable, comfortable, and even cool. The buses would have been considered luxurious to a previous generation—electrical outlets, wireless internet, personal entertainment centers, and vending machines for drinks and snacks. The whole experience also had to be convenient. Routes were divided into super-trunk, trunk, local, and connector or jitney systems. The trunk buses traveled on the closed roads, so there was no stopping for lights or pedestrians—direct and non-stop. Transfers were walk-off/walk-on—timed and seamless, except for the jitneys, which operated on demand the way airport shuttles did in the old days. Systems in 2010 had already begun offering arrival information through smart phones at every stop. Now the city distributed an application that alerted the passenger to stop what they were doing and head to the corner to catch the next bus. The application was enormously popular because those who used it waited less than three minutes on average at the stop. Individuals could even reserve a seat on a particular bus through their phone for an additional charge.
    - **Walking and biking:** The city turned some of the smaller closed roads to hike and bike trails that crisscrossed the city. Walking and biking were much safer on these roads than on a busy street. WTG also launched another public-relations campaign on the health benefits of walking and biking, sponsored biking clubs and clinics, supported local bike shops, and received substantial contributions from bicycle manufacturers for the new concept of *active transportation*. As a result, the city was recognized as one of the nation's five healthiest cities.
    - **Autonomous vehicles:** The most innovative system, however, were the autonomous vehicles, first tested by Google in the 2000s. These driverless cars ran around the city,

> taking people to places for which the fixed transportation system was less convenient. An individual reserves the car or calls it in real time through an application on the phone. The car arrives, usually in less than five minutes, and drives the individual and up to three other people to whatever destination they entered into the phone. The driverless cars avoid the need for large parking lots and garages where cars sit for hours waiting for a 20-minute drive. They are being used approximately 75 percent of the daylight hours, where the average utilization of personal vehicle is less than 5 percent. After all, the real purpose of transportation is mobility, getting from place to place, rather than necessarily owning the means to do so. We had learned the lesson from the Software as Service (SaS) movement in the 2010s. You did not have to own the software to get the processing service from the computing cloud.

The plan is in place. Funds from investment, taxes, and fees have been budgeted. It is now time to see if the system actually meets its goals

Potential Implications for Transportation

The Many Ways to Go scenario has the following implications for transportation:

- Funding revenues fragment as the fuel tax declines. A carbon tax offers the possibility of transportation funding.
- DOT partnerships and advocacy campaigns encourage cultural transitions for demand-reduction strategies via telepresence alternatives to work and personal services (e.g., trips to the doctor and retail shopping).
- Federal, state, and local funding may shift to expand broadband access (urban/rural) that enables access to telepresence. The result could be less funding for transportation.
- Populist legislative efforts may reduce or suspend gasoline taxes to counter the rising costs of fuel.
- Agencies may use land (asset) sales or co-development of former road corridors that are now closed to traffic.
- General funding may decline as government dollars are allocated specifically toward new innovative transportation systems. This could impact general funds used in maintenance and revitalization of legacy assets.
- Freight and supply chain systems may shift, driven by advanced information technologies.
- The bus/jitney industry may fragment as new players compete for rising demand. This could lead to innovation driven by competition—or a negative consumer experience if the industry's market structure does not allow for sustainable business models (e.g., hyper-competition leads to failed companies and abandoned routes).
- Agencies may manage (design and build) new transportation assets along highway systems (e.g., bike paths) used in *active transportation*.
- Autonomous vehicle fleets and transit partners may use new multimodal hubs along highways to bring last-mile services to suburban communities.

Escape to the Center

Table 6.12 shows the key elements for this scenario.

Table 6.12. Key Scenario Elements for Escape to the Center.

Scenario	Factors*	Key Drivers	Scenario Kernel
Escape to the Center	C U F3 C V F3	High population density Low mobility capacity Low security	The lack of mobility and increased threats to their well-being drive people out of the suburbs and into the city, reducing the demand for transportation—the arrival of the vision for the advocates of smart growth.

* Key: R = row-wise analysis; C = column-wise analysis; U = unrotated factors; V = varimax rotated factors; F = the factor number in each set.

The end of the Automobile Era was difficult, but it provided lots of options for policy makers and the public alike. One of the most serious questions was about the form of the metro environment after the automobile. No one disputed the fact that, besides simple population growth, the high-rise structure and air conditioning for Southern cities, the automobile had done more to shape the form of the country's metropolitan areas than anything else. Cities in the Northeast and the industrial Midwest achieved their form before World War II. As a result, they are denser and have more transportation options. The rest of the cities are defined by their freeways rather than their rail lines. They are less dense because they were built for the automobile. With automobiles disappearing under the pressure of high gasoline prices and carbon taxes, will the population find another independent means of transport, build a complex (and expensive) multimodal transportation system, or give up on physical mobility altogether and retreat to the Internet? Of course, these options were not mutually exclusive, but one other choice remained. They could simply move. Pre-World War II populations had much more effective and robust transportation systems, but they also used them less than the generations who followed them. People lived closer to the factory and office and closer to family and friends. A short bus or train ride or even a short walk would get them to the places they needed to go, be it school, work, shopping, or entertainment. Of course, the automobile changed all that. They and the freeways they drove on gave rise to the sprawling suburbs, acres of shopping malls, and all the other amenities of metropolitan life.

So would that density continue with the automobile much less useful than it was before? If people did want to move, it would still take some time. Clustering around a company complex is not as easy as buying a home that one can afford and driving to wherever the work is. Real estate people in the 1990s said that distance to work was about the fifth most important consideration when people went to buy a home. Ahead of the commute were price, safety, education, and distance to amenities, in no particular order. Now, of course, distance to work was just as important, if not more important, than any of these. Nevertheless, it would take decades to reshape the cities, and even then the remnants of the automobile society would linger on, just like the form of the rail-city remains in New York, Boston, and Chicago.

Nevertheless, the advocates of what used to be called smart growth are cheering now that their dream might become a reality. Denser city living was a tough sell in the first quarter of the century when the automobile was still viable, particularly for families with children and for aging Boomers who want to be close to social services and cultural hubs. Now it might be thrust on a reluctant population by necessity. Of course, kids growing up in that environment would not

know the difference. They did not remember square miles of quarter-acre plots with identical homes in rows. And even the adults will adapt because that is what we do. We may hanker for the suburbs, but one can only be nostalgic for so long. After a while, the urban environment becomes a way of life.

At the same time, the advocates of smart growth should not celebrate too soon. Just because people have to live closer to work does not mean that work has to be the central city at all. Rather than an overall increase in population density, those businesses might move to the suburbs where the people already are, rather than stay in the city. Suburban complexes are already quite common, such as Silicon Valley in California, Route 128 in Boston, and the Energy Corridor in Houston. People will still have to move to be closer to these relocated businesses. They cannot live just anywhere because they will not have the transportation they used to have to get to work. But they might move from one suburb to another, leaving the central city even less populated than it was. That form would create islands of density in an overall less dense metro area, much like Northern Virginia where business clusters around the metro stops.

However, it turns out that the automobile built the post-War city, and it will have a big effect when the city can no longer sustain that form. Nothing this substantial changes overnight, and remnants of the past remain, but the city of 2050 could well have a much denser feel than was true in the previous 100 years.

Potential Implications for Transportation

The Escape to the Center scenario has the following implications for transportation:

- Transportation agencies and engineering-solution providers shift toward place-based planning principles, taking a more holistic approach to multimodal systems.
- Incentives are created to cultivate market demand for high-density-based transportation systems among early adopters.
- DOTs push for regulatory certainty on funding commitments to urban-based multimodal hubs. Constraints (e.g., fines and taxes) are placed on competing sprawl developments that might undermine efforts.
- DOTs, transit providers, and real estate developers form stronger partnerships and may merge organizationally. This allows them to reduce overhead costs and leverage existing assets (e.g., highway lanes transformed into bus-only lanes or rail) to meet the needs of rising urban center demands.

Meltdown

Table 6.13 shows the key elements for this scenario.

Table 6.13. Key Scenario Elements for Meltdown.

Scenario	Factors*	Key Drivers	Scenario Kernel
Meltdown	R U F1 R V F1 C U F1 C V F1	Climate change Environmental quality/sustainability Gas/carbon tax Government role Population density	The pessimistic scenarios for climate change ended up being more accurate than the optimistic ones. As a result, the most important priority for the next few decades was struggling with nature rather than growing the economy.

* The reversed scenario takes the cluster of drivers loading negatively on the F1 factors as the operative drivers. Key: R = row-wise analysis; C = column-wise analysis; U = unrotated factors; V = varimax rotated factors; F = the factor number in each set.

The debate over climate change is over. Abrupt climate change, a term coined in 2005, was now the new reality. The atmosphere contained a number of reinforcing feedback loops that, once started, had run out of control. The most obvious was the methane locked into the permafrost of the Arctic. Once the permafrost started to melt, it released methane into the atmosphere, which in turn increased the temperature and melted more permafrost, which released more methane, etc. The cycle was a runaway by 2025. Ice in Greenland and glaciers all over the world were melting at an increasing rate, and the breakup of the Ross ice shelf in Antarctica added meters to the sea level, inundating low-lying areas around the country and around the world. The East and Gulf Coasts were hit the hardest. Florida, Louisiana, and Texas lost valuable land. Millions were displaced, and whole industries, like the petrochemical industry in Houston and the tourist industry in Florida, relocated or simply closed. Transportation planners scrambled to rebuild roadways and train lines in more inland locations. In the end, adaptation, the incremental ability to protect society and its way of life from climate change, seemed an impossible venture for what would be required in the face of the actual emergency.

The new reality followed decades of wrangling about whether climate change was real or not or, at least, whether it was produced by emissions from human activity. The sensation produced by Al Gore's *An Inconvenient Truth* in 2006 did not last. In fact, people looked at record snowfalls and bitter winters in the early 2010s as evidence that the scientists were wrong or, even worse, that they had made up the whole thing to advance a pro-government, anti-capitalist agenda. But those who took the warnings seriously did not agree either on what was to be done. The first response was to reduce the amount of carbon that people put into the atmosphere—the mitigation strategy. The Kyoto Protocol, negotiated by Gore when he was still vice president, was supposed to be the first step in that direction, but it was a feeble step—no enforcement, so almost no effect. And the big emitters, the United States and the large developing countries, were not even signatories. Emissions from emerging economies like India, Indonesia, and the newly industrialized resource-rich regions across Africa exceeded expectations. By 2020, the levels of GHGs, some of which would continue to warm the atmosphere for centuries, were so high that further reductions would not contain temperature increases in any meaningful way. The days for significant mitigation had passed.

But the public mood shifted rapidly once the runaway warming started. Legislation to control carbon was put into effect, even though scientists said that it could well be too little too late. The

large carbon dioxide emitters were severely restricted by a carbon tax that would get close to $90 per ton—coal plants, manufacturing facilities such as petrochemicals and cement, and of course transportation. Farmers had to use less diesel and fertilizer, and some famines ensued. The constructional industry had to get its material locally and cut down on waste altogether.

The transition was brutal, but surprisingly people rallied to face the crisis together. Of course, there were disagreements on how and when things should be done, but the political fights for turf and political advantage were mostly gone. The United States, the most flexible (and some would say the most disorganized or even chaotic) society led the way. It implemented the draconian measures—not liking it but realizing that the threat existed.

It was a generation before life settled into a more local, more quiet, less hectic, and less stressful way of life. Some of the old-timers longed for the good old days of go-go and perpetual motion. Most, however, taught their children that the world they had grown up in was a unique historical moment, but that they were glad it was over. And their children looked back on the society of their grandparents and felt superior, as most generations are wont to do when they look to the past. They judged that their ancestors had done as well as they could under the circumstances, but that they, the present generation, had achieved a much better life. They saw the effects of the catastrophe as progress to them, as most generations are also wont to do.

Potential Implications for Transportation

The Meltdown scenario has the following implications for transportation:

- Government support and industry self-interest lead acceleration of vehicle electrification to respond to new demand (and public-relations battles of brands that are not transforming their fleets). Fuel-based revenues decline because of this.
- The need for maintenance dollars increases to repair roadways and railways impacted by rapid climate change (e.g., heat and rains/flooding).
- Coastal transportation infrastructure may be lost or need to be rerouted.
- Transportation may shift toward city-center-oriented transportation hubs.

CHAPTER SUMMARY

This chapter described the expected baseline and alternative futures, created based on the trend and rate of change for that trend, using 21 drivers identified in the scenario planning workshop (see chapter 5). The research team created six multi-driver scenarios based on the analysis of the 18 drivers (three drivers were combined with other similar drivers). The analysis included development of a cross-impact matrix, which aided the statistical assessment of the 21 drivers.

The output of chapter 6 becomes the basis for Phase II: Vision Development. The next chapter summarizes the Phase I results.

CHAPTER 7: SUMMARY AND CONCLUSIONS

SUMMARY

The Phase I objective was to:

- Identify future factors and trends that could significantly influence infrastructure maintenance, preservation, and renewal.
- Assess the likelihood and impact of various scenarios on future needs.

This objective was achieved by identifying:

- Key drivers.
- Their future trends.
- The expected (baseline) future describing these drivers and trends.
- Alternative futures with different trends.

These items formed the basis for developing six multi-driver scenarios that characterize the transportation environment in 30 to 50 years.

To accomplish the research, the team assessed the future impact of key drivers in 13 technical areas using six worlds from project 20-83(07), *Sustainable Transportation Systems and Sustainability as an Organizing Principle*. Each of the 13 technical areas had a number of drivers that influenced the six worlds described in the 20-83(07) study. The team identified 67 unique drivers and, from those drivers, developed six different worlds for each of the 13 technical areas.

The technical-area drivers and worlds became the knowledge base used to develop 21 specific drivers expected to influence future transportation needs. This output was derived initially from a one-day workshop facilitated by the research team's futurist. These 21 key drivers covered the majority of the original 67 technical-area drivers. Three of the 21 key drivers were combined to produce 18 key drivers for analysis. These drivers were described in terms of the expected future based on trends (direction of change) and rates of change. Alternative futures were also described in this manner. The drivers were analyzed using statistical tools to determine which drivers were most related to each other and then combined to create theme areas. These theme areas became the six multi-driver scenarios.

CONCLUSIONS

The research team concluded that the scenario planning methodology, with multi-driver scenarios based on multiple drivers, is the appropriate methodology to assess impacts on highway infrastructure maintenance, preservation, and renewal needs during the next 30 to 50 years. The research team also concluded that six multi-driver scenarios that describe possible transportation environments in 30 to 50 years would meet the Phase I objectives. Namely, the scenarios describe future factors and trends that could significantly influence infrastructure maintenance, preservation, and renewal. The baseline future shows expected trends, their rate of change, and their likely impact on future needs; the alternative futures show other possible trends, rates, and impacts.

Some key observations regarding this work are as follows:

- The six worlds created for each of the 13 technical areas helped develop the research team's understanding of the future state of each technical area.
- The 21 key drivers represent most of the drivers mentioned in the technical-area descriptions.
- The six multi-driver scenarios are based on an extensive statistical analysis of the drivers and their relationship to each other, as well as the expected baseline and alternative futures.
- Scenarios can reflect a negative future, a positive future, or a future somewhere in between. This variability will influence the extent of development of new materials, tools, approaches, and technologies to meet future needs for maintaining, preserving, and renewing the highway infrastructure.

The research team believes that the work accomplished in Phase I and described in this report establishes a sound basis for Phase II: Vision Development. An updated work plan for Phase II is discussed in chapter 8.

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APPENDIX A: TYPICAL LITERATURE REVIEW SUMMARY

LITERATURE REVIEW FOR SCHALLER 2010

Schaller, B., 2010. "New York City's Congestion Pricing Experience and Implications for Road Pricing Acceptance in the United States." TRB 2010 Annual Meeting, CD-ROM, Transportation Research Board, Washington, D.C.

1. Likely changes to our world that will affect transportation (what is the change)

   - Conclusions from the document:

     The focus of this article was on a proposal for congestion pricing in New York City and specifically in Manhattan. While the proposal was blocked by the New York State Legislature, it had received widespread public support. The paper presents the background behind the proposal and how public debate affected public acceptance. The paper assesses the implications of the New York City experience for public acceptance and adoption of road pricing nationally with a focus on **mileage-based fees**, widely seen as the **long-term future of transportation finance**. The key section of this paper is the section on lessons for acceptance and adoption of road pricing. Building public support is one general lesson and includes key elements such as vision of top-level leadership, linking pricing to a broader plan involving transportation climate change and land use goals, public involvement to shape the final plan, public education and outreach, leadership from civic, business, labor, environmental and advocacy groups, and availability of federal funds. In the area of design of pricing proposals is recognition that a small group of people can stop the approval of a proposal. The pricing proposal has to demonstrate and convince all drivers that they will benefit from the scheme. Funds generated through congestion pricing will be used for roadway improvements that will benefit a larger number of drivers.

   - Charts/graphs/trends from the document:

     One table compares congestion pricing plans. A second table summarizes views on congestion pricing in New York City.

   - Predictions:

     Congestion pricing will be implemented provided that support can be built for pricing proposals and that the design of pricing proposals are ones that likely will gain approvals from state legislatures or other elected bodies.

2. Likely effect of that change

   - What will the changes impact (name all):

     Reduce congestion within major cities and improve air quality.

- What were the other impacts mentioned:

  Ties with other sustainability plans are critical.

3. Likelihood of occurrence of change (high, medium, low)

   - While not specifically stated, it appears to be highly likely to occur.

4. Rate of change (when and how fast)

   - Probably slow as it takes much effort to obtain public support for pricing proposals.

5. Names of national expert in field of expertise (to build references to contact on interviews)

   - The author, Bruce Schaller.

6. What could mitigate the change's effect?

   - Anything mentioned in the document:

     Relatively small groups of people can block these kinds of proposals.

   - Anything else you know of that could mitigate the change:

     Lack of any of the key elements in building public support.

7. Other key references listed in the article or document that might be of benefit

   - List of references could provide additional information on other state/cities and countries that are implementing congestion pricing of the nature discussed in this article.

APPENDIX B: SIX WORLDS

OVERVIEW

This research uses the six future worlds developed in *Sustainable Transportation Systems and Sustainability as an Organizing Principle for Transportation Agencies* from NCHRP Project 20-83(07). These worlds frame the larger discussion of the concerns surrounding the maintenance, preservation, and renewal of highway infrastructure.[1]

Key drivers (discussed in chapter 3) greatly influence and shape any future world. The six worlds paint a broad picture of what the future would look like under the driver circumstances. The result is:

- Two negative worlds (Crisis World and Dirty World).
- Two moderate worlds (Mega World and Suburban World).
- Two positive worlds (Wonder World and Green World).

The research team has integrated the six future worlds with the 13 technical areas (see chapter 4). The resulting framework aids in several important areas of this research:

- It helps identify the likely changes that transportation infrastructure will undergo.
- It illustrates how the technical areas interact and change under the circumstances of each scenario and to what effect.
- It exposes the potential challenges and opportunities that the United States must address should these scenarios come to fruition.

The following sections give descriptions, implications, challenges, and opportunities that transportation agencies will face in the six worlds. (The original report, *Sustainable Transportation Systems and Sustainability as an Organizing Principle for Transportation Agencies*, contains more details on these worlds.)

CRISIS WORLD

Description

In the first of the two negative worlds, Crisis World, the United States experiences extreme hardship and a continuing cycle of crises due to the combination of slow economic growth, stagnant technological developments, and intensive environmental degradation.[2] The impacts from climate change are so profound that financially destitute government agencies can no longer effectively manage the situation. Government spending on transportation drops below the historic average of 1.95 percent of GDP per year, only furthering the severity of the situation.

Implications for Transportation

A high dependence on fossil fuels, extremely high gas prices, and high unemployment levels move access to basic transportation beyond the reach of many individuals.[3] The public largely

[1] ~~Booz Allen Hamilton. "Sustainable~~ Transportation Systems and Sustainability as an Organizing Principle for Transportation Agencies." 2011.

[2] *Ibid* pp. 69–74.
[3] *Ibid* pp. 69–74.

rejects user fees for transportation revenue generation, resulting in diminished funding for transportation investments. Private organizations maintain the operation and maintenance of high-demand routes through tolling. Most transportation systems and infrastructure outside mega-regions collapse due to the extreme scarcity of resources.

Crisis World brings many changes for transportation agencies.[4] Agencies adopt new processes and organizational structures in an attempt to adapt to the difficulties of limited funding. Citizens likely recognize negative impacts from climate change and are more willing to adapt their lifestyles in support of a more sustainable society.

Challenges

State agencies face numerous challenges under Crisis World, but chief among these challenges is an extreme scarcity of financial resources.[5] Reduced tax revenues make it impossible to maintain much of the transportation infrastructure and services. Agencies reduce or eliminate many transportation facilities and services, and curtail long-term planning in favor of focusing on managing short-term emergencies. Poor data collection and analysis impair agencies' ability to make effective decisions.

Opportunities

Crisis World presents several important opportunities for state transportation agencies.[6] The various crises incentivize individuals to change unsustainable behaviors and adapt to the new reality. As a result, agencies may be able to leverage this sentiment to implement more sustainable policies and programs. Widespread deficient infrastructure provides the opportunity for transportation agencies to repair and replace crumbling roads and bridges using environmentally sustainable methods and materials.

DIRTY WORLD

Description

The second negative world, Dirty World, is very similar to Crisis World.[7] The United States' economy grows at a very slow rate, technology development and adoption are slow, and fuel prices are high. The largest difference between the two scenarios is that climate change impacts the United States at a much slower rate. The lack of frequently occurring crises eliminates the visible evidence of climate change. As a result, the public is less supportive of measures to increase sustainability in this world. This world is very difficult to live in, but adaptation and management are possible.

[4] *Ibid* pp. 69–74.
[5] *Ibid* pp. 69–74.
[6] *Ibid* pp. 69–74.
[7] *Ibid* pp. 75–78.

Implications for Transportation

The largest implications of Dirty World emerge from the combination of an aging population without a young working population to fund the United States' various programs.[8] The dependent population quickly drains financial resources, and low economic growth and immigration levels do not replenish the funds.

Challenges

Many of the challenges state agencies face result from the scarcity of financial resources.[9] Agencies cannot afford to maintain all transportation facilities and infrastructure, so they must make difficult decisions about where to spend their limited resources. Agencies may need to decommission lower-demand facilities and transit routes, but low staffing levels mean there is likely poor data for decision making. Perhaps the most difficult aspect of this scenario stems from the lack of a highly visible crisis from climate change. Without such a crisis to stimulate strong public support, implementing the required drastic changes is both unpopular and very difficult.

Opportunities

One of the opportunities present in Dirty World is that state agencies can leverage the high cost of carbon-based fuel and the ubiquitous environmental concerns as focusing events to encourage individuals to switch to cleaner fuels and alternative modes of transportation.[10] Users understand their impact on the degradation of transportation facilities and begin to make decisions for greater conservation. The lack of crises enables state agencies to invest in long-term solutions, instead of spending their limited resources on constantly emerging crises.

MEGA WORLD

Description

Mega World is the first of two neutral scenarios.[11] This scenario is largely a continuation of the current trends in the United States. Many of the drivers exhibit growth in the most likely range. Economic growth follows expected patterns and continues at a steady 2.4 percent of the GDP per year, spending on transportation continues at the historical average of 1.95 percent of the GDP, and carbon-based fuels are both expensive and still the dominant source of transportation energy. Environmental changes are slow and manageable, the population continues to grow, and new vehicles and infrastructure technologies are slowly adopted across the United States. Guideways, connected vehicle systems, and self-driven cars are common occurrences on the streets of Mega World.

The two neutral scenarios are differentiated by where the population growth occurs.[12] In Mega World, the population concentrates into 10 different mega-regions across the United States.

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[8] *Ibid* pp. 75–78.
[9] *Ibid* pp. 75–78.
[10] *Ibid* pp. 75–78.
[11] *Ibid* pp. 78–81.
[12] *Ibid* pp. 78–81.

These mega-regions are not megacities but instead contain a mixture of interconnected cities, suburban areas, exurban areas, and even rural communities. These different areas are all connected through "a complex network of economic, infrastructure, and geographic relationships."[13]

Implications for Transportation

Several important implications arise from Mega World.[14] The various levels of government begin to shift funding transportation away from fuel taxes and toward user fees. Smart growth and planned developments grow out of the increased costs for transportation. Motorists use interstates less frequently and almost exclusively for moving goods and freight. The collapse of infrastructure outside the 10 mega-regions leads states to carefully manage and coordinate the decline. Finally, young immigrant families provide a strong tax base that supports an otherwise aging and dependent population.

Challenges

The largest challenges that state transportation agencies face in Mega World originate from the development of mega-regions.[15] These mega-regions require the reorganization of transportation planning activities across cities, states, and regions. State agencies must form joint planning organizations to facilitate intergovernmental collaboration and communication. Metropolitan planning organizations and mega-region planning organizations become the most important sources of centralized planning efforts, with support from the federal government. Areas outside the 10 mega-regions face distinct challenges in acquiring funding for their infrastructure and transportation needs.

Opportunities

Two likely opportunities emerge from the circumstances in Mega World.[16] First, deteriorating infrastructure, tight budgetary constraints, and high fuel costs result in greater privatization of the operation and maintenance of transportation infrastructure and services. Second, the formation of mega-regions enables transportation agencies to pool resources, address large transportation concerns, and solve pressing challenges.

SUBURBAN WORLD

Description

Suburban World is very similar to Mega World.[17] Many of the major drivers follow the expected projections. Economic growth continues at a steady 2.4 percent of the GDP per year, spending on transportation stays at the historical average of 1.95 percent of the GDP, and carbon-based fuels are still expensive and the dominant source of transportation energy.

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[13] *Ibid* pp. 27–28.
[14] *Ibid* pp. 78–81.
[15] *Ibid* pp. 78–81.
[16] *Ibid* pp. 78–81.
[17] *Ibid* pp. 81–83.

The largest difference between the two worlds is how population is distributed and concentrated throughout the worlds.[18] Suburban World experiences a migration to "the suburbs, small towns, and second tier cities."[19] The resulting world's dispersed demographics and land usage resemble that of early 20th century America. The adoption of new transportation technology and high fuel prices facilitate the movement to the suburbs, with most workers able and choosing to either work from home or from sites near their homes.

Implications for Transportation

Several important implications arise from Suburban World.[20] An aging and dependent population creates a drain on social services and government expenditures. This challenge is largely offset by a young immigrant population that provides a strong tax base to replenish the country's financial resources. Agencies begin to privatize many transportation systems and the operation and maintenance of infrastructure, leading to a more financially sustainable system. The privatized system provides for economic and social needs, but it is unclear if the system meets environmental needs.

Challenges

A significant challenge that transportation agencies face in Suburban World is the high cost of maintaining transportation infrastructure and services over a large geographic region.[21] Agencies must develop mechanisms to establish priorities when allocating scarce resources. State agencies may choose to privatize the operation and maintenance of transportation infrastructure to reduce the burden that they bear.

Opportunities

Several opportunities occur in Suburban World that state agencies can leverage.[22] First, the vast geographic distribution of the population and high costs of maintaining infrastructure encourage state agencies to search for alternative methods to provide services. Partnerships between private companies and state agencies form to maintain and operate highway infrastructure and provide transportation services. Second, the implementation of new sensor and data-gathering technologies improves resource allocation and decision making. Finally, the increases in technologies that allow individuals to live and work where they like foster competition among communities that wish to attract new residents. Much of the competition is based on the services that localities provide and the tax rates that are present.

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[18] *Ibid* pp. 81–83.
[19] *Ibid* p. 81.
[20] *Ibid* pp. 81–83.
[21] *Ibid* pp. 81–83.
[22] *Ibid* pp. 81–83.

WONDER WORLD

Description

Wonder World is the first of two positive scenarios and is characterized by technological wonder, strong economic growth, and manageable challenges.[23] The domestic economy expands rapidly from higher than expected growth at 3.5 percent of the GDP. Rapid technological advancement and adoption serve as a catalyst for new economic growth areas. Petroleum and carbon fuel prices increase drastically, but technological improvements and alternative fuel sources defray the costs to consumers and the environment.

The population grows rapidly thanks to advances in medicine and high immigration levels.[24] Environmental challenges are less than expected, but agencies can manage these changes when they do occur. The public supports user fees as a means for generating transportation revenue. Technological improvements in vehicles and infrastructure are inexpensive and available to a large population through economies of scale. Guideways, self-driven vehicles, and other technological innovations decrease congestion and enable individuals to choose where they would like to live and work. Many choose to work from home or remote locations through telepresence systems. Others use various advanced multimodal transportation systems to commute.

Implications for Transportation

The technological marvels and economic boom of Wonder World have several implications for transportation agencies.[25] Advanced data-collection methods and real-time pricing schemes enable agencies to actively manage congestion, mitigate environmental harm, and efficiently use energy. The increasing availability of data arms decision makers with more information and enables better choices. A premium is placed on the ability of transportation agencies to remain flexible and able to quickly adopt changing technologies.

Challenges

The challenges that state transportation agencies face in Wonder World revolve largely around difficulties adapting to new technologies.[26] Technologies like transit systems, new revenue-generation methods, and advanced means for freight movement may not link across all regions. Some transportation technologies and funding systems may require new infrastructure and the development of a regulatory framework. The use of new fuel sources requires agencies to find new means to generate revenue.

Opportunities

Opportunities abound for state agencies in Wonder World.[27] Increased financial resources mean that agencies are able to implement new types of technologies to improve transportation facilities

[23] *Ibid* pp. 84–86.
[24] *Ibid* pp. 84–86.
[25] *Ibid* pp. 84–86.
[26] *Ibid* pp. 84–86.
[27] *Ibid* pp. 84–86.

and services. Agencies can afford to increase capacity, improve infrastructure, and maintain the existing infrastructure. New monitoring technologies improve data collection and analysis, resulting in better decision making regarding the allocation of resources.

GREEN WORLD

Description

Many of the positive aspects of Wonder World carry over to Green World: high economic growth, high rates of technology advancement and adoption, and strong levels of population growth.[28] The largest difference between the two scenarios lies in Green World's broad social imperative to conserve resources and move toward a more environmentally sustainable and green society. The United States invests broadly in innovative green technologies and infrastructure, and adopts new policies and programs that encourage conservation. Individuals change behaviors to increase society's sustainability.

Technological advances, high carbon-based fuel costs, and ubiquitous alternative energy sources virtually eliminate the usage of fossil fuels.[29] Suburban areas disappear, and families move into dense urban developments. One of the downsides of this scenario is the implementation of restrictive regulatory, economic, and social controls by varying levels of government in search of environmentally friendly practices.

Implications for Transportation

Green World has several important implications for transportation systems and agencies.[30] First, increased coordination and collaboration begin to occur among and between the layers of government. The federal government engages in the planning process and develops universal standards and regulations for transportation systems. Federal agencies work with state and local governments to ensure that these measures are properly implemented and enforced. Second, state and local governments take on a larger role in transportation administration as an increasing reliance on local, multimodal transit emerges. States and local governments take charge in operating and integrating the various modes of transportation into a highly efficient smart system.

Challenges

The challenges that state transportation agencies face in Green World are similar to those in Mega World.[31] The mega-regions require interstate collaboration and communication in planning. Regions must develop joint planning organizations to ensure that systems are interoperable. Decreasing personal-vehicle ownership creates a strong reliance on publicly provided transit, which state and local governments must provide. The move away from carbon-based fuel sources requires the adoption of new technologies and changing the current vehicle stock.

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[28] *Ibid* pp. 87–89.
[29] *Ibid* pp. 87–89.
[30] *Ibid* pp. 87–89.
[31] *Ibid* pp. 87–89.

Opportunities

The opportunities for state agencies are likely broad since government control is quite extensive under this scenario.[32] Centralized planning puts the control in the hands of the government, and individuals cede some autonomy in favor of achieving a more environmentally sustainable society. Users are more likely to accept various transportation funding mechanisms, including user fees and privatized transportation systems. A denser population, distributed into urban regions, requires less infrastructure investment across regions than in other worlds, and services only need to be concentrated in focused areas.

[32] *Ibid* pp. 87–89.

APPENDIX C: TECHNICAL AREAS

DEVELOPMENT OF TECHNICAL AREAS

Six members of the project team developed the technical areas, using their expertise in the area and information from the literature and Internet review. They then vetted them to SMEs on the research team, other SMEs within TTI with expertise in the specific technical area, and SMEs external to TTI.

This chapter describes each technical area in terms of:

- General characteristics of the technical area.
- Key drivers of that technical area.
- Plausible future scenarios for the technical area based on the six-world framework from the 20-83 (07) study (see Appendix B for more details):
    - **Crisis World:** low technology level, slow growth, high resource prices, and rapid climate change; therefore, a changing urban form and public commitment to sustainability.
    - **Dirty World:** Crisis World but less extreme.
    - **Mega World:** an extrapolation of current trends with more concentration in urban centers.
    - **Suburban World:** Mega World but with movement to suburbs and second-tier cities.
    - **Wonder World:** high technology level, high growth, and distributed population.
    - **Green World:** high growth but sustainable, more restriction, and less individual freedom and choice.

LIST OF TECHNICAL AREAS

The 13 technical areas are:

1. Technology and innovations.
2. The environment.
3. System performance.
4. Security.
5. Natural-resource availability.
6. Finance and budget.
7. Human resources.
8. Coordination.
9. Regulations and policies.
10. Demographics.
11. Customer needs and expectations.
12. Traffic.
13. Safety.

The RFP lists safety and security as one area, but the research team split this into security (technical area 4) and safety (technical area 13) since the subjects are distinctly different.

TECHNOLOGY AND INNOVATIONS TECHNICAL AREA

Overview

The development of technology will impact transportation in various ways. Technology can radically change the practice of maintenance, preservation, and renewal of highway infrastructure by reducing deterioration with better predictive tools, by providing alternative transportation options, by increasing the durability of construction materials, and by reducing traffic-related crashes.

Rather than listing all the different technologies that are available or anticipated in the near future, this document tries to capture the behavior or trends of technologies that are emerging or may become significant in the next 30 to 50 years due to various drivers. The descriptions of the six worlds discuss how and to what degree these emerging trends could affect the kinds of technologies that receive the most focus.

Drivers of Technology and Innovations

The drivers behind developing and implementing new technologies and innovations fall into these categories:

- Demand for efficiency and capacity.
- Demand for safety measures.
- Demand to meet legal and regulatory requirements.
- Adequate funding.

Demand for Efficiency and Capacity

Demand for efficiency will increase due to the inability to expand capacity. Different users and different needs can demand efficiency. For example:

- The rise in private-vehicle ownership and frequent use of private vehicles will lead to technologies that allow smarter vehicles and technologies that help reduce congestion.
- The rise in public-transit ridership will lead to technologies in innovative public transportation systems.
- The rise in freight movement will promote technologies to build stronger pavement materials and an innovative freight transportation system.

Demand for Safety Measures

Demand for safety measures also drives technology development in today's transportation industry and will continue to be a major driver as the transportation network becomes more sophisticated and complex.

For example, demand for safety will push for smart vehicles, better monitoring systems, better design of physical roadway, new construction practices, improved traffic safety enforcement, and better decision-making tools to increase the safety of drivers and construction workers.

Demand to Meet Legal and Regulatory Requirements

Demand to meet legal and regulatory requirements will change how private industries conduct business and encourage them to invest in technologies tailored to meet these requirements. For example:

- Stringent environmental regulations will lead automobile makers to invest in technologies that support clean technologies such as electric vehicles and vehicles made mostly out of recyclable materials.
- The construction industry will face continuing legal and regulatory requirements dealing with worker safety such as ergonomic regulations and exposure to chemicals, which may lead to technological improvements. Legal and regulatory requirements will also impact construction equipment technologies.

Adequate Funding

Adequate funding is essential to create affordable and alternative sources of energy, advance vehicle technology, and effectively manage traffic. As the current financing mechanism becomes inadequate, policy makers will work to find alternative sources of funding. For example:

- Policy makers will seek public support for direct user fees.
- Public-private partnership will become more common as government seeks to meet the public's demand.

As more funding becomes available, the desire to invest in advanced technologies and to test those technologies will grow.

World Descriptions

The drivers in the technology and innovations technical area are present to varying degrees in each world (figure C-1).

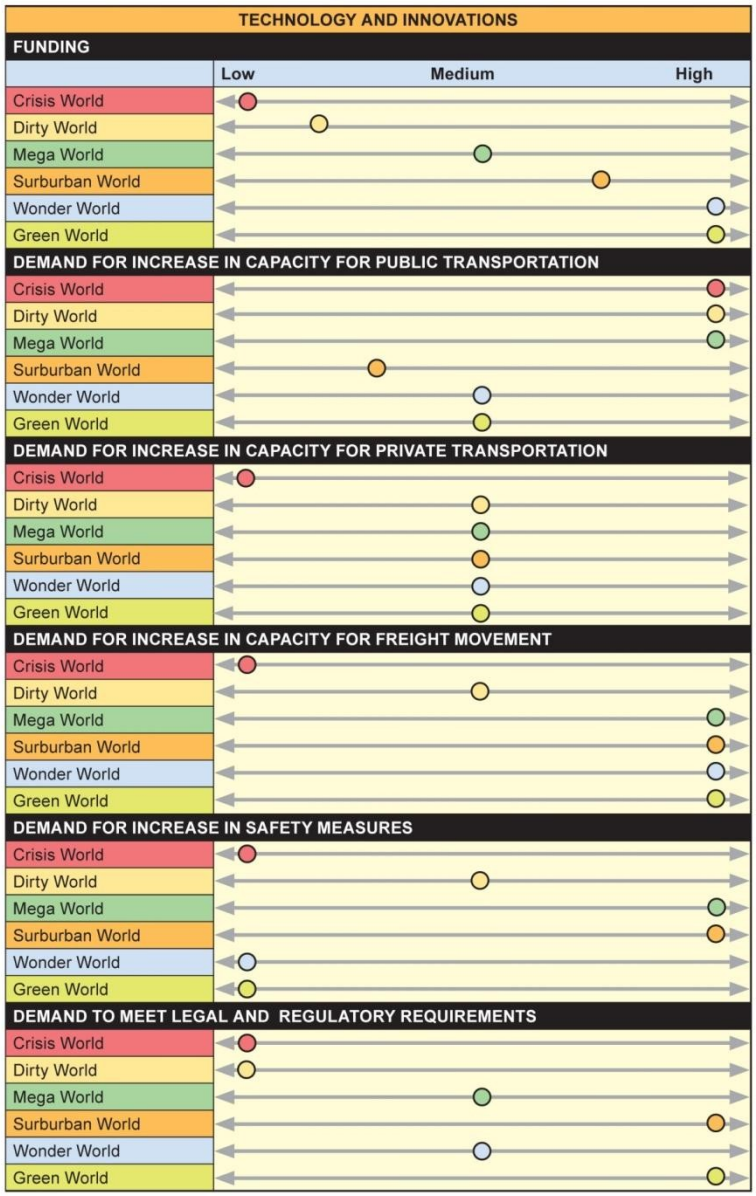

Figure C-1. Drivers for Technology and Innovations Technical Area.

Crisis World

The following conditions concerning technology and innovations occur in Crisis World:

- The unemployment rate is high, and the economy is in poor shape. This leads to less funding for investing in technology.
- Depletion of natural resources leads to a sharp increase in fuel prices. High fuel prices coupled with the unemployment rate reduce the demand to travel by private automobiles, which in turn creates heavy reliance on public transportation for traveling. With growing demand for public-transit services, the government initiates research into alternative energy, innovative public transportation systems, and technologies to improve transportation agencies' operations.

- The demand for finished goods decreases, which in turn leads to less freight movement. However, less freight movement does not equate to slower deterioration of highway infrastructure. Many of the existing highway infrastructures are already in poor condition. The government searches for decision-making tools to optimize prioritization of rehabilitating projects, which can alleviate the pressure on obtaining capital.
- The government invests in technologies that allow transportation agencies to be more productive and efficient in operation and providing services to meet the public's most basic and urgent needs.

Dirty World

The following conditions concerning technology and innovations occur in Dirty World:

- The unemployment rate starts to decline, and the economy slowly rebounds. However, funding is still insufficient to adopt new technology.
- Fuel prices remain high, and the demand for public transportation is still significant. As more people find work in the city, people start to commute more by means of private automobiles.
- As the economic conditions improve, the demand for finished goods also rises, resulting in more freight movement.
- In addition to technologies that can improve agency operations, the government seeks new technologies related to safety as traffic increases and the number of crashes starts to increase. The government invests in technology to reduce accidents by examining technologies such as real-time sensors, innovative roadway designs, vehicles that communicate with other vehicles on the road by telematics or Wi-Fi technology, and skid-resistant tires.
- The government recognizes the need to enforce regulations to manage technological development and adoption. However, the government still struggles to develop a comprehensive guideline to promote sustainable growth.

Mega World

The following conditions concerning technology and innovations occur in Mega World:

- The economy starts to improve around the existing mega-regions. Both the government and the private sector have more available funds for technological development and adoption.
- Most of the wealth is concentrated in 10 regions of the country. Areas with high concentrations of people rely heavily on the current urban infrastructure. With no room to grow outward, the government may be challenged to find innovative ways to transport people into and within the city. This results in faster development of technologies that support new construction materials, which are lighter but stronger; new equipment that can assist with building around tight spaces in densely populated areas; real-time monitoring systems for added security; and alternative transportation modes. The government also seeks ways to alleviate congestion by investing in technologies that allow people to live and work remotely.

- Some people continue to commute to work in the comfort of their own vehicles, which increases traffic during morning and afternoon rush hours. This leads to innovations in vehicle technologies such as driverless cars. Driverless cars allow people to be productive even when they are sitting in traffic. Driverless cars also result in greater system efficiency with minimal vehicle spacing required and help reduce congestion. Removing the driver (human) element also greatly improves safety.
- Freight movement increases as demand for finished goods rises.
- With high traffic all around the nation, ensuring the safety of pedestrians, construction workers, and drivers remains very important. Both the government and private industry invest in technologies that can further improve traffic safety toward zero accidents. Technologies that improve safety may include non-invasive advanced road condition-monitoring tools, automatic vehicle inspection systems, and automatic detection of truck operator fatigue and alertness.
- Government regulations receive more emphasis, and the government is in the process of diligently reviewing and setting higher standards to protect the health and welfare of people, and to minimize the negative impact on the environment.

Suburban World

The following conditions concerning technology and innovations occur in Suburban World:

- Unlike in Mega World, people sprawl out into every region of the country.
- Adequate funding produces more research, development, and adoption of technology. Technology allows people to live and work virtually anywhere. Technology creates virtual meetings and holograms. Development and interest in auxiliary technology supports remote access and cyber networking as ways to conduct business.
- Advancement in virtual technology results in less travel by public transportation for commuting. However, demand still exists for private automobiles for leisure travel as people spend more time with their families and travel to secluded places for relaxation.
- As people become more conscious of sustainability issues, demand rises for technological investments in mass production and adoption of electric vehicles, better and longer-lasting batteries, construction of recharging stations, and smart grids that allow cars to recharge from home.
- The rise in demand for finished goods results in higher freight movement. As freight movement increases, ensuring the safety of drivers gains attention. The government enforces stronger regulation on the trucking industry to ensure the safety of its people. Technologies such as automatic vehicle inspection systems, automatic detection of truck operator fatigue and alertness, and cloud computing (which allows enhanced security measures) help the trucking industry meet regulations.
- Along with the rise in freight movement, the government is also interested in reducing the impact of freight movement on highway infrastructure. It investigates technologies such as real-time nondestructive pavement and bridge condition assessment tools, and advanced construction materials such as self-healing concrete.

Wonder World

The following conditions concerning technology and innovations occur in Wonder World:

- People are free to live and virtually work wherever they choose.
- Both the private sector and public sector have an unlimited source of funding to invest in new technology.
- People are equally using private and public transportation as a means of traveling. Individual vehicles and public transportation systems are coordinated and are in sync to integrate with other technologies.
- All private vehicles are electric, can be charged from home, and can cruise on automatic driving settings.
- Public transportation has evolved into semi-private transportation modes: people use an individual pod car, which leaves the house, goes to a central location, and joins a larger carrier to travel further into popular areas.
- Safety issues no longer exist since all accidents and negative impacts can readily be predicted and prevented in advance.
- Demand for finished goods increases, which increases freight movement. However, shipments travel via a separate system such as underground tunnels or tube-like tunnels (aboveground or airborne). This prevents cargos from commingling with individual vehicles or semi-private transportation systems.
- The government has comprehensive regulations in place that promote sustainable growth.

Green World

Green World is similar to Wonder World but is highly regulated. Technology develops in similar ways as in Wonder World.

The following conditions concerning technology and innovations occur in Green World:

- Although funding is unlimited, the market is limited to exploring new technologies and techniques, which limits innovations and technological advancements in the field of transportation.
- The government manages funds and develops technologies that will be used in the future. For example, the government may determine the different modes of transportation that will be needed in the future, considering the existing infrastructure and aiming to maximize its use. So, the government may set requirements to support only development that ties into and can coexist with the existing system. The government does not consider innovations and technological advancements.

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THE ENVIRONMENT TECHNICAL AREA

Overview

Environmental requirements and changes in the environment and climate are critical factors that state transportation agencies must consider in the 21st century. Changes in the project planning, design, construction, maintenance, and operational phases are necessary if a sustainable transportation system and sustainable society are to evolve this century.

Environmental policy and regulation will largely determine the adjustments the state transportation agencies will require. Changes in climate will also need to be considered. Environmental policy and climate change will impact the cost of delivery of highway construction, reconstruction, rehabilitation, and maintenance projects. Environmental requirements will affect pavements, bridges and other structures, drainage, other roadside features, and traffic control devices.

Drivers of the Environment

The drivers for protecting the environment fall into these categories:

- Policy and regulation.
- Environmental quality.
- Sustainable/green construction.
- Climate change.

Policy and Regulation

Existing policies and regulations have greatly changed the business model used by state transportation agencies over the last 40 years. The National Environmental Protection Act (NEPA) signed in 1970 to promote the enhancement of the environment has established procedural requirements for Environmental Assessments (EAs) and Environmental Impact Statements (EISs). Over time, these regulatory requirements have changed the planning, design, construction, reconstruction, rehabilitation, and maintenance of transportation facilities. These changes have added cost to projects while providing an improved environment for society.

Environmental policy and regulation are also developed and enforced at the state, regional, and local level. Coordination of these various governmental levels and governmental agencies responsible for developing and enforcing these regulations can be a challenge to state transportation agencies. For example, some projects must satisfy federal agencies including the Environmental Protection Agency (EPA), U.S. Army Corps of Engineers, U.S. Coast Guard, Fish and Wildlife, and state and regional agencies with authority in air quality and water quality.

Policy and regulation needs will impact state transportation agencies in the following areas:

- Project development requirements.
- Project delays/project costs.
- Coordination requirement.
- Permitting of materials-mining, processing, and manufacturing sites.

Environmental Quality

Environmental quality is a general term and, as used in this report, specifically concerns air, water, and noise (to a lesser degree).

Air quality requirements impact highway location, design, materials selection, construction, reconstruction, rehabilitation, and maintenance activities. The following are some of the requirements to ensure air quality:

- The National Emission Inventory (NEI) of the U.S. EPA tracks air-quality, health-based parameters for carbon monoxide (CO), nitrous oxide (NOx), sulfur dioxide (SO_2), PM10 particulate matter, PM2.5 particulate matter, ozone, and lead. NEI uses these data to identify nonattainment areas in the United States, which are governed by legislation. NEI also monitors volatile organic compounds (VOCs) and ammonia (NH3).
- Regulations control the generation of dust during mining, processing, and manufacturing of materials and during construction, reconstruction, rehabilitation, and maintenance of highway facilities.
- Greenhouse-gas generation is an important air quality consideration. GHGs include carbon dioxide (CO_2), methane, nitrous oxide (NO), and SO_2. Approximately one-third of the CO_2 generated in the United States results from transportation of goods and services. Reduction in internal-combustion-engine vehicle miles traveled and the use of alternative fuels (among other approaches) could help reduce CO_2 generation from the transportation sector.

Government agencies regulate water quality associated with the extraction, processing, and manufacturing of materials used for construction, reconstruction, rehabilitation, and maintenance of highways. Runoff from paved roadway surfaces can affect water quality, as can drainage associated with highways both during and after construction.

Noise associated with highway transportation facilities is an important consideration in some urban areas. Pavement surface type can somewhat address this concern.

Environmental quality needs will impact state transportation agencies in the following areas:

- Project development requirements.
- Project delays/project costs.
- Permitting of materials-mining, processing, and manufacturing sites (air and water quality).
- Dust and water quality during construction, reconstruction, rehabilitation, and maintenance of highway facilities.

Sustainable/Green Construction

The 1973 oil embargo caused increased use of sustainable or green construction alternatives in the 1970s. Interest in these technologies and other technologies has been renewed, especially in the last three years. This trend could well continue into the remainder of this decade.

Sustainable/green construction includes selection of designs, materials, construction processes, and long-life facilities including pavements, structures, and traffic services devices. Specific activities include the design, construction, reconstruction, rehabilitation, and maintenance of highway facilities to conserve energy, reduce emissions, and reduce the use of natural resources. Impacts are for both users and non-users during facilities upgrade and repair activities.

Since sustainable/green construction options are often cost effective, this driver is somewhat independent of other environmental drivers, including policy, regulation, and other environmental considerations. For example, the use of reclaimed asphalt pavement (RAP), recycled portland cement concrete (RPCC), shingles, and other byproduct materials in pavement structures is both economical and green.

Sustainable/green construction needs will impact state transportation agencies in the following areas:

- Pavement and structures type (steel, concrete, asphalt, etc.) selection.
- Reconstruction, rehabilitation, and maintenance alternative selection.
- Materials selection for pavements, bridges, and traffic services operations.
- Design of long-life facilities.
- Recycling (RAP, RPCC, shingles, etc.).

Climate Change

A companion NCHRP research effort, 20-83(5), has identified several key areas of climate change:

- **Temperature:** Climate change models predict an average increase in U.S. temperatures of 2.9°F by 2050 (the range predicted is 0.5°F to 6.9°F). On average, models predict minimum temperatures to increase more than maximum temperatures during this period.
- **Precipitation:** Models predict that precipitation will increase an average of 2.3 percent by 2050 (the range predicted is −11 to +10 percent). They also predict greater increases in moisture in the winter as opposed to declines in precipitation in the summer. Storm intensity will increase, and thus precipitation rates are also likely to increase. Hurricane numbers will likely decrease; however, the storms intensities are likely to increase.
- **Sea-level rise:** Models predict that the sea level will rise 0.5 to 2 feet by 2050. The most likely increase in sea level will be 10 inches. Storm floods near the ocean will likely be more severe.
- **Wind intensity associated with hurricanes.**

State transportation agencies will need to adjust to these projected climate changes. Some of these changes include:

- Location of facilities to handle sea-level changes, storm intensity, low-land flooding, and hurricane intensity.
- Drainage structures (size and perhaps location) to handle the increased amount and intensity of precipitation.
- Erosion control to handle changes in precipitation patterns.
- Design considerations and material selection to handle temperature changes, minimum and maximum temperatures, the increase in precipitation, changes in soil conditions, storm intensity including wind, etc.
- Construction practices.

World Descriptions

The drivers in the environment technical area are present to varying degrees in each world (figure C-2).

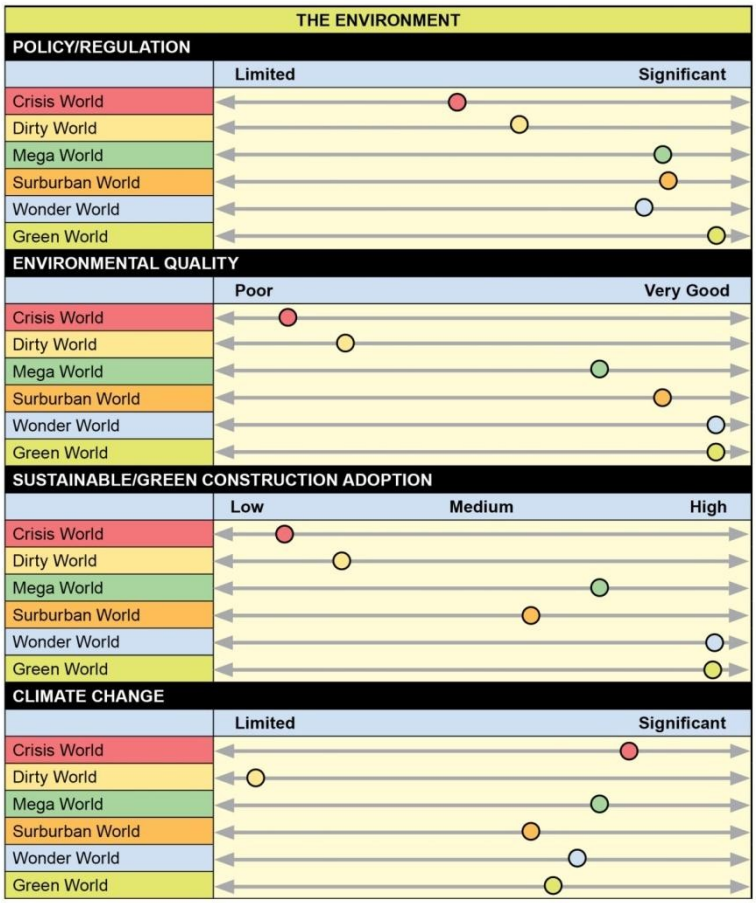

Figure C-2. Drivers for the Environment Technical Area.

Crisis World

The following conditions concerning the environment occur in Crisis World:

- Persistent and long-term crises range from environmental to economic and social. The United States lacks the means to adequately respond to challenges, leading to significant changes in daily status quo for the population. Policy and regulation associated with environmental considerations are alternately strict or relaxed because the nation is unable to meet regulatory standards due to the economy.
- Environmental quality and sustainable construction operations receive attention but are largely not successful.
- Climate changes are faster than expected, and significant natural disasters occur, with more tornados, high-intensity rainfall events, wet winters, high wind, and hurricanes.

Dirty World

Dirty World is similar to Crisis World, with the exception that crises related to climate change are less pronounced.

The following conditions concerning the environment occur in Dirty World:

- Environmental policy and regulation are steady, and change is slow because climate changes are slower than expected.
- Environmental quality and sustainable construction operations receive attention. Those that are cost effective are slowly implemented.

Mega World

Mega World is presented as a status quo where current trends in the economy and population growth continue.

The following conditions concerning the environment occur in Mega World:

- The general population is concentrated into 10 major mega-regions.
- Policy and regulation associated with environmental considerations are steady, and progress is made in air quality, water quality, and reductions in GHGs. Little progress is made in nonattainment areas because technology improvements are offset by increases in urban populations.
- Climate change is as expected. Since populations have increased and are concentrated, severe weather events cause more damage.
- The economic, green construction alternatives are adopted during a traditional slow time frame.

Suburban World

Suburban World is very similar to Mega World, with the notable exception that the population is diffused throughout the country in smaller secondary and tertiary cities.

The following conditions concerning the environment occur in Suburban World:

- Policy and regulation associated with environmental considerations are steady, and progress is made in air quality, water quality, and reduction in GHGs. Improvement in the number and sizes of non-attainment areas is evident.
- Climate change is as expected. Increases in population and the dispersion of the population cause more severe weather damage events than in the present world.

Wonder World

Wonder World is characterized by faster than anticipated economic and technological development. As a result, there is generalized decentralization of the economy.

The following conditions concerning the environment occur in Wonder World:

- Policy and regulations associated with environmental considerations are steady, and progress is made in air quality, water quality, and reduction in GHGs, primarily as a result of developed technology and more rapid adoption of technology. This progress is somewhat faster than that associated with Mega World or Suburban World.

- Climate change is as expected, and its impact on highway transportation is mostly managed.
- Considerable progress is made in green construction.

Green World

Green World resembles Wonder World. The primary difference, however, is that Green World has broad consensus about the importance of sustainability and the need for a green society. This new outlook permeates public-policy decisions and results in stricter regulations.

The following conditions concerning the environment occur in Green World:

- The substantial increase in policy and regulation associated with environmental considerations affects the business model of state departments of transportation.
- Significant improvements are made in air quality, water quality, and reduction in GHGs. Often these improvements are costly to society.
- Climate change is as expected, and its impact on highway transportation is mostly managed.
- Significant progress is made in green construction.

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SYSTEM PERFORMANCE

Overview

The performance of transportation as a system depends on a number of key drivers. Although a basic aim would be to have a system capacity slightly greater than the demand on that system, this is rarely realized. The factors affecting this imbalance are generally the lag time between capacity expansion and general growth demand arising from population growth, and the lack of capital, which is often earmarked for more urgent social concerns. Moreover, a huge regulatory burden often weighs down progress and implementation of new projects. Thus it is often easier to maintain the existing infrastructure. And while the interstate system has generally been well kept and maintained, the quality of regional infrastructure and transportation services has historically been somewhat spotty. This is largely due to regional and state politics, which may not be concordant with a national view.

Naturally two of the key drivers in keeping the performance of the transportation system as a whole in a state of balanced equilibrium are the interplay between maintenance of the existing

system and the expansion of that system or even to newer systems. Much of this state of equilibrium depends on vehicles for financing both major and minor projects.

Worldwide conditions, along with the long-term nature of the political landscape and other externalities, may principally affect the drivers that shape our world and our nation's response to those conditions specifically. Dark scenarios, the likes of Crisis World and Dirty World, evolve rapidly in response to one or more catastrophic shocks. Conversely, a rosy future is most likely to evolve due to a period of long-term political and social stability, like Wonder World or Green World.

It is likely that the future holds a mixture of good and bad happenings that shape our world; much of this is controlled by geopolitics and macroeconomic conditions. Such worlds may drift from the present state of affairs to one of either Mega World or Suburban World. Again, the pathway to those outcomes will be largely dependent on the unforeseen externalities in play over a period of several decades.

Drivers of System Performance

The drivers of system performance fall into these categories:

- Infrastructure maintenance.
- Infrastructure expansion.
- Land availability for infrastructure.
- Energy.
- Vehicle technology.

Infrastructure Maintenance

Infrastructure maintenance depends largely on the health and well-being of the local state and county tax base. This becomes the default necessity if infrastructure expansion is stifled. The interplay between maintenance and renewal will depend on the cost of labor and the degree of mechanization that can be used to automate menial maintenance tasks.

Infrastructure Expansion

The expansion of the infrastructure depends largely on the ability to fund huge mega-projects, either by PPP, tax incentives, direct taxation, or national deficit financing. The cost of land and the necessity to invoke eminent domain powers also markedly affect the ability to expand infrastructure. When compared to the more expensive highway systems, alternative non-road infrastructures may be more easily expanded on existing easements.

Land Availability for Infrastructure

Land availability for infrastructure is interdependent on population growth: if urban centers grow, land availability for infrastructure expansion is limited. On the other hand, if suburban populations expand, low-priced land tends to be plentiful. Problems with eminent domain acquisition persist, however, as most transportation to suburban dormitory townships is inevitably highway based.

Energy

Energy efficiency needs to be incentivized by governmental oversight and regulation. Supply and demand of energy pricing, particularly oil and gas, are affected by a combination of world conditions and domestic policy for drilling, exploration, and distribution. The use of alternative modes of transportation (air, rail, and sea versus road) is governed by oil pricing.

Vehicle Technology

Vehicle technology is affected by the age of the fleet and the affordability of new technology in new vehicles. Technology will lead to enhanced in-vehicle safety features and improved highway capacity via automatic routing and traffic control. Autonomous vehicles of the future promise to improve both safety and capacity.

World Descriptions

The drivers in the system performance technical area are present to varying degrees in each world (figure C-3).

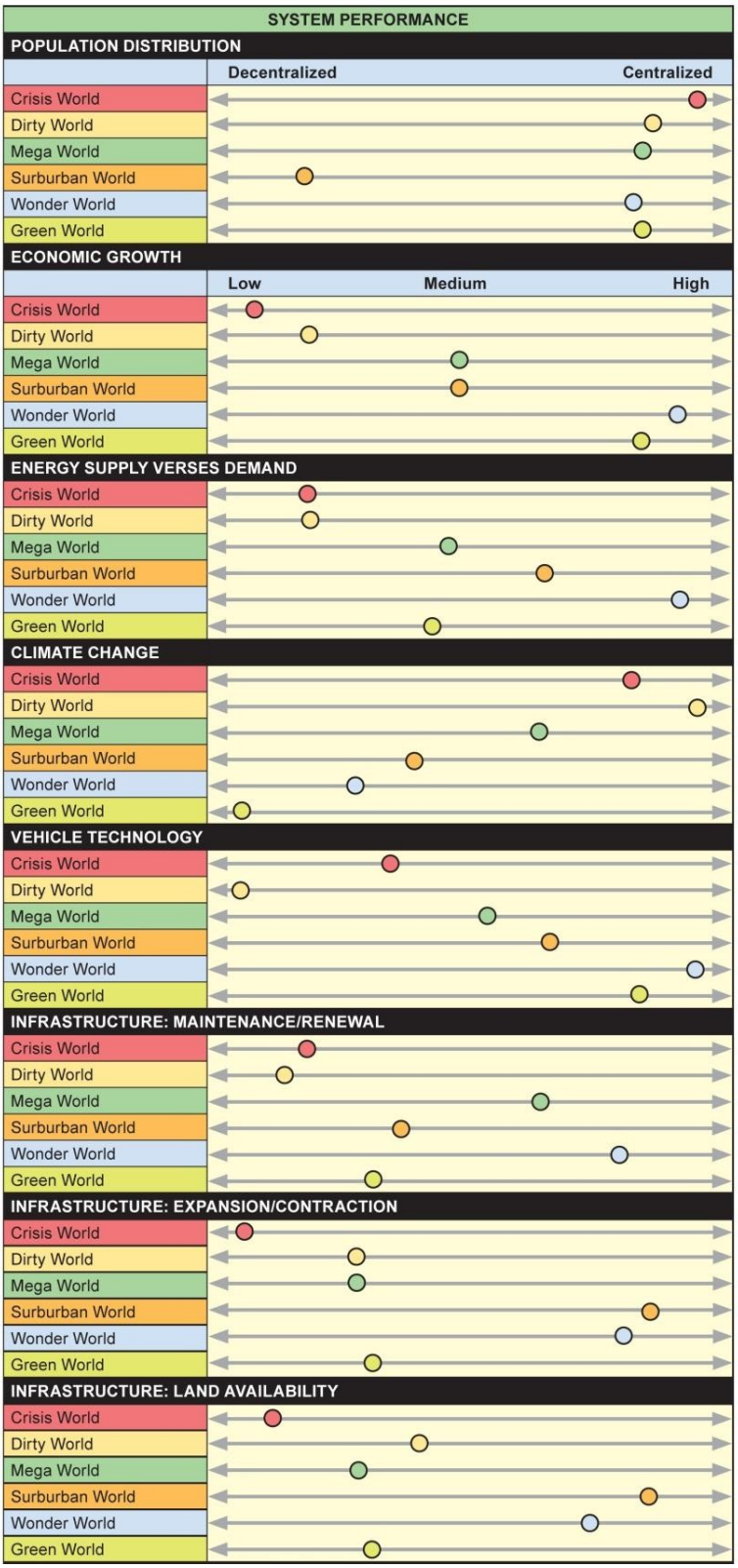

Figure C-3. Drivers for System Performance Technical Area.

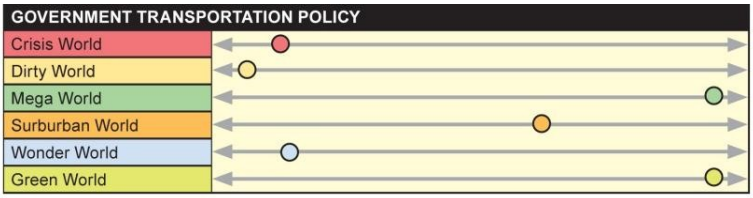

Figure C-3. Drivers for System Performance Technical Area (Continued).

Crisis World

The following conditions concerning system performance occur in Crisis World:

- Crisis World is exemplified by worldwide catastrophes that arise because of warfare and natural disasters. In response to this government revenues are, of necessity, diverted to react to those crises. Suppose that the warfare is dire. Several nukes are dropped, and in the Middle East the dominant international supplier of oil is in short supply. What remains goes largely to the two post-2025 principal world consumers: China and India. In response, the United States has deregulated oil exploration; both on and off-shore supply barely meets demand—much of this is dedicated to external military uses. The government uses the oil supply as a principal source of taxation revenue; thus, there is considerable tax built into the pump price. This tax wholly covers the transportation infrastructure cost. Much of this transportation infrastructure is necessary to keep the manufacturing for the U.S. war machine operative.
- The aging of the infrastructure is due to lack of funding and suitable transportation personnel. This leads to continual and rapid deterioration. Since none of the 20th century infrastructure is replaced after 2020 when it reaches its design lifespan, it becomes impossible to renew and effectively maintain. In crisis mode, only essential repairs are done where life safety is at risk—only renewal of near-collapsed bridges or completely failed pavements. Rural roads deteriorate rapidly due to wear and tear; graders are put back into wholesale service to maintain many secondary routes. Capital is insufficient for expanding any infrastructure beyond 2020. Suburban sprawl occurs with low-density land use and ill-maintained roads. Without management, land owners use their land as they please. This results in ribbon development and random placement of commercial opportunities or multi-family housing.
- Gas and diesel remain the principal sources of fuel, with high prices ($9) due to worldwide shortages. Imports are restricted due to the volatility of the Middle East. Electric power is mostly generated from coal-fired plants. Both transportation and electric-power generation cause considerable pollution. Adoptions of new technologies are limited due to their high cost. The vehicle fleet has aged due to lack of imports because foreign manufacturers are busy with their own war orders. The availability of new vehicles and technology is mostly dedicated to military and homeland security users.

Dirty World

The following conditions concerning system performance occur in Dirty World:

- In the year 2025, an unknown lone-operative sets off a massive improvised explosive device at a U.S. nuclear power plant. The threat remains of similar additional devices or dirty bombs being set off. Electric-power operators, with governmental encouragement, power down all other operating nuclear power plants. Lost capacity is made up by the provision of (dirty) oil and coal-fired plants. This leads to considerable CO_2 overload into the atmosphere, and what gains had been made in reducing carbon emissions to pre-1990 levels are rapidly lost and exceeded by a wide margin. Government funds, being stretched, are directed to internal security arrangements.
- Constant threats, mostly from ideologues from abroad, over the years have been made toward the railroads. Amtrak subsidies are removed; consequently, rail passenger transport folds. The class one railroads have been attacked several times by terrorists; freight handlers have thus lost confidence in the railroads and resort entirely to trucking. The railroads subsequently go broke and mothball their facilities.
- Toxic acid rain from dirty manufacturing and transportation proliferates and leads to decimation of forests and wildlife. Pollution from agriculture runoff, particularly nitrates, leads to poor ground and surface water quality; the ecosystems in many of the waterways are decimated. The fishing grounds in the Gulf are destroyed by a combination of these actions together with regular oil spills.
- Infrastructure ages and deteriorates rapidly due to lack of previous investment and renewal. Patch and repair remain the preferred methods of pavement and bridge maintenance. Some limited bridge renewals are conducted, but these largely use cheap imported steel from China. Pavements use low first cost due to the limited supply of capital and the inability to secure bonds. Suburban sprawl is rife; low-density land use with poor quality roads is the norm. Laissez-faire capitalism permits land owners to use their land as they please, resulting in random land usage.
- Imports are restricted due to the volatility of the Middle East, but domestic oil and gas supply experience resurgence, both offshore and in Alaska. Thus gas and diesel remain the principal sources of fuel, with high prices ($8) due to substantial taxation for transportation usage. Electric power is mostly generated from (dirty) coal-fired plants. Both transportation and electric-power generation cause considerable pollution.
- Limited adoption of new technologies occurs due to high cost and the fear of cyber attacks. The vehicle fleet has aged due to lack of imports; the availability of new vehicles and technology is reserved for and dedicated to homeland security and military users.

Mega World

The following conditions concerning system performance occur in Mega World:

- In the year 2025 there is a significant infusion of new generation of genetically modified crops, and thus agriculture comes back in vogue. This puts a high price on all arable land. Those people not involved in the rural agriculture enterprises concentrate in the large urban centers in high-density housing communities.

- As China and India gain ascendency to leading world powers, they no longer remain the world's preferred manufacturers. Much of the heavy manufacturing in the early 21st century that was lost to the Asian tigers is brought back home to the United States; they locate and concentrate where the low-cost labor forces are. Some return to the rust-belt mega-regions, while most go to the low-cost right-to-work southern mega-regions. Housing concentrates primarily in the mega-regions due to the proliferation of job opportunities across many sectors.
- Transportation becomes an intensification of present trends. And although many attempts are made to diversify, there remains a preponderance of single-passenger car journeys in the mega-regions.
- Existing rural infrastructure and highways are adequately maintained and renewed as required, but the system is not expanded. Capital supply is adequate, and under PPP and governmental arrangements, the interstate systems within and surrounding the mega-regions are expanded.
- Agriculture gains in productivity, particularly due to the new generation of genetically engineered crops and smart herds, and puts high value on rural land. Therefore, suburban sprawl is controlled and limited, although some ribbon development between sub-mega-regions exists.
- Mega-region concentrations of population cause extreme pressure on land development. Thus tunneling and elevated highway expansion become the (very expensive) norm.
- Gasoline and diesel remain the principal fuel sources, but there is some use of hybrid-electric vehicles. By 2050, gas prices are close to $7 per gallon.
- New technologies are cost prohibitive; therefore, there is limited uptake. New semi-autonomous vehicle system technologies are mostly the domain of the corporate and governmental fleets. For others, driving-assisted technologies are mostly limited to low-cost smart phone applications.

Suburban World

The following conditions concerning system performance occur in Suburban World:

- In 2025, China's economy catches up with the United States', which is no longer the competitive leader in the worldwide markets. But due to its innovative nimbleness, the U.S. economy bounces back and becomes the world's leading provider of robotic light and nano-manufacturing goods and associated services.
- Rural land remains low priced. Thus, elite acreage "lifestyle blocks" form the basis of endless suburban sprawl throughout the country. This becomes a preferred lifestyle for adults with families due to moderate cost and a high perceived level of personal safety. Youths and young professionals, however, prefer to go to college and work in one of the many small to medium (sub-million) cities distributed throughout the country. The historic large cities remain, but their urban centers continue to be ghettoized and plagued with urban blight.
- Existing rural infrastructure and highways are well maintained and renewed as required, but the system is not significantly expanded. Capital supply is adequate, and under PPP and governmental arrangements, the interstate systems between and surrounding main cities are expanded. The old urban centers continue to age and decay due to an array of

intractable social problems. And although it is mostly inexpensive to live in the cities, they are abandoned.

- Agriculture is depressed, leading to advancing many off-the-grid lifestyle acreage developments. Land remains relatively inexpensive. High-tech and light-manufacturing gains in productivity lead to demands for dependable workforces in regional and suburban locations. Therefore, suburban sprawl is pronounced with much ribbon development between larger centers.
- Gasoline and diesel remain the principal fuel sources, but there is some 20 percent use of hybrid-electric vehicles. By 2050, gas prices are close to $5 per gallon.
- New technologies are cost prohibitive; therefore, there is limited uptake. New semi-autonomous vehicle system technologies are mostly the domain of the corporate and governmental fleets. For others, driving-assisted technologies are mostly limited to low-cost smart phone applications.

Wonder World

The following conditions concerning system performance occur in Wonder World:

- In 2025, the United States has made huge progress in the biotechnologies. A new generation of genetically engineered crops that combines food and medicine is developed. The common 20th and early 21st century diseases of obesity, heart disease, and diabetes are under control as a result of these new foods. Furthermore, due to genetic-inspired nano-medicine, cancers become more easily treated and cured. Life expectancy rapidly improves and jumps to 100 years old. Many people continue to continue to work, by choice, well into old age.
- Taxation is lowered because the United States becomes the world's provider of the patented wonder foods; via exporting, a healthy external revenue stream ensues. The national debt is thus paid down. A constitutional amendment requires a balanced budget.
- Users pay directly for services, mostly provided by the private sector. Environmental problems, while not eliminated, are largely under control through a self-motivating principle known as the "polluter pays."
- Capital supply is adequate. A mixed system of fully privatized, PPP, and government-owned arrangements for the interstate system exists. Some routes compete for users. Planned preventative maintenance is the normal expectation—users do not tolerate poorly maintained assets.
- New types of private-sector-led transportation systems are developed that relieve on-road freight congestion, such as a freight shuttle system and a new generation of heavy-lift airships. This relieves the historic highway system, and the focus is more on the expansion of commuter traffic capacity.
- A laissez-faire zoning system prevails, leading to much mixed-density land use. Land in both the cities and rural regions remains a sound investment.
- Hybrid gasoline and diesel-electric vehicles are the norm. Alternative electric and/or hydrogen vehicles are becoming commonplace for corporate fleets. By 2050, the price of a gallon of gasoline has reached over $6, forcing further innovation and changes in travel behavior.

- Private-sector incentives to use alternative vehicle systems are common. Semi-autonomous vehicles are commonplace; this in effect increases both safety and highway capacity.

Green World

The following conditions concerning system performance occur in Green World:

- In 2025, the United States emerges into a technology-driven green world. Technology is heavily used to control the potential adverse effects of pollutants in the environment. While such services are largely provided by the private sector, they are required through much regulation of every sector of government. Although a near-utopian ideal, the society is heavily regulated in an Orwellian sense of necessity.
- Electricity is derived 50 percent from renewable energy sources (wind, hydro, geothermal, and ocean currents) and 50 percent from natural gas and coal (clean carbon processes)—the latter of necessity to ensure load-balancing of peak demands.
- Supply-side economics prevail through stern regulation, along with strict commodity control. Society continues to strive for restorative justice and redistribution of wealth through social engineering, high taxation, and welfare transfer payments. Although many people are mostly happy with these arrangements, others aspire to the more laissez-faire Wonder World.
- The government maintains the existing system well but attempts to shrink it wherever possible to enable greener alternatives to be introduced. New types of vehicles require expensive new guideways. New conventional highway systems are no longer supported or funded by the government.
- Strictly controlled zoning and land use patterns emerge. As a means of control, the government buys up land at every opportunity. Ailing businesses are nationalized, and then "greened." When successful, they are spun off but with government ownership of the land.
- Electric and hydrogen fuel-cell vehicles become the expectation, although some heavy-duty gas and diesel legacy vehicles remain. By 2050, the price of a gallon of gasoline has reached over $10 per gallon, made up principally of punitive taxes to force the switch to green vehicles. Government mandates require semi-autonomous high-efficiency guideways to be used for main trunk transport.

SECURITY TECHNICAL AREA

Overview

Transportation security must consider terrorism, piracy, organized crime, illegal drug manufacturing and trafficking, and smuggling. Transportation risks may include weaponization of the asset by direct attack en route, sabotage, or a Trojan Horse–style attack into a facility. These risks may be mitigated by one of many strategies, including internment, staging,

prioritization, conscription, and prohibition, as well as by administrative security measures and technology for monitoring and isolating the assets.[33]

The importance of transportation security continues to increase with globalization, regional integration, and increasing connections between communications and transportation technologies.[34] Unfortunately, safety and security of highway infrastructure are such that land and transportation security receives the least emphasis since it is less pressing than other modes of transportation such as aviation and maritime.[35] Transportation safety encompasses maintaining a healthy condition of the nation's critical transportation infrastructure such as roads, railways, airways, waterways, canals, and pipelines.

One of the biggest issues in safety and security of transportation is the lack of system-based, comprehensive risk evaluation and vulnerability assessment of the entire transportation system. This leads to underestimating the risks. This situation occurs because information needed for securing transportation systems exists in multiple agencies that frequently do not share information horizontally (across the same level of government) or vertically (across local, state, and federal government). Cross-jurisdictional information sharing and triangulation can help generate better investigative leads and strengthen legal cases against criminals.[36]

Drivers of Security

The drivers for ensuring security fall into these categories:

- Travel demand and supply.
- Technology development.
- Funding.
- Globalization.

Travel Demand and Supply

Shifts in demographics have a large impact on travel demand and supply. Where one chose to live and how one chose to work will indicate the type of transit systems that need to be built to create a balance in U.S. mobility systems. For example:

- The Millennial generations may be more interested in walking/bicycling and more aware of climate change and sustainability. This may require an inter-city transit system such as rails and bike paths.
- Expansion of the current transportation network system to meet the travel demand will bring new challenges to the transportation agencies since understanding the

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33 David A. Moore. "Application of the API/NPRA SVA Methodology to Transportation Security Issues." *Journal of Hazardous Materials,* 2006, pp. 107–121.

34 Joseph Szyliowicz. "Dilemmas of transportation security." *Transportation Quarterly*, 1997, pp. 79–95.

35 R. William Johnstone. "Not Safe Enough Fixing Transportation Security." *Science and Technology*, 2007, pp. 51–60.

36 Siddharth Kaza, Jennifer Xu, Byron Marshall, and Hsinchun Chen. "Topological Analysis of Criminal Activity Networks: Enhancing Transportation Security." *IEEE Transactions on Intelligent Transportation Systems,* 2009, pp. 83–91.

interdependencies between other existing transportation modes is critical to maintain the safety and security of the transportation infrastructure. Decision makers need to consider the entire transportation route as it impacts individuals, businesses, and the nation.

- As more transportation infrastructure starts integrating between nations, added security measures may be required to adequately protect the people. Continuous monitoring and evaluation of the safety and security measures need to be in place.

Technology Development

The United States is in the forefront of developing technologies to increase the level of safety and security in the transportation area. For example**:**

- ObjectVideo is developing intelligent capabilities specifically tailored to meet the needs of the transportation industry that work effectively in diverse environments. The technology accurately detects, identifies, classifies, and tracks objects and people; and automatically detects activities that violate user-specified security-rule violations and suspicious activities.[37] Currently, the Transportation Security Administration (TSA) relies on a variety of devices, ranging from simple metal detectors to sophisticated three-dimensional x-ray machines to screen baggage and individuals for explosives or other prohibited items.[38]
- Development of ITS technology allows for real-time traffic management and faster decision making.
- More recently, to enhance transportation security, vehicles with small, reliable, inexpensive, interoperable chemical and biological sensors along with expert processing capabilities are being developed to protect against terrorist threats (Marion G. Ceruti, 2008).
- There is a need to understand how developments in technology will assist transportation agencies in responding to emergencies and in helping to reduce terrorist attacks.

Funding

The lack of funding and lack of comprehensive training development and delivery plague all of the transportation industry. Although technology and advanced equipment allow for enhanced surveillance, there is still a great demand for increased law enforcement presence and expanded worker security training. Far more human interventions may be required as challenges arise from fairly applying these new technologies. Justifying the cost related to operating and maintaining the security measures may be difficult.

Globalization

Rise in international travel and globalization allows terrorists more opportunities to enter into the United States. Controlling the flood of foreigners also becomes challenging at the border. In response to the threats, the United States implements advanced technology to screen and track

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[37] Niels Haering and Khurram Shafique. "Automatic Visual Analysis for Transportation Security." *IEEE*, 2007, pp. 13–18.

[38] Huseyin Cavusoglu, Byungwan Koh, and Srinivasan Raghunathan. "An Analysis of the Impact of Passenger Profiling for Transportation Security." *Operations Research*, 2010, pp. 1287–1302.

the movement of cargo and individuals and differentiates between low-risk traffic and high-risk traffic prior to entrance to the United States. However, an increase in international traffic lends itself to heightened security measures as terrorists and criminals become smarter.

World Descriptions

The drivers in the security technical area are present to varying degrees in each world (figure C-4).

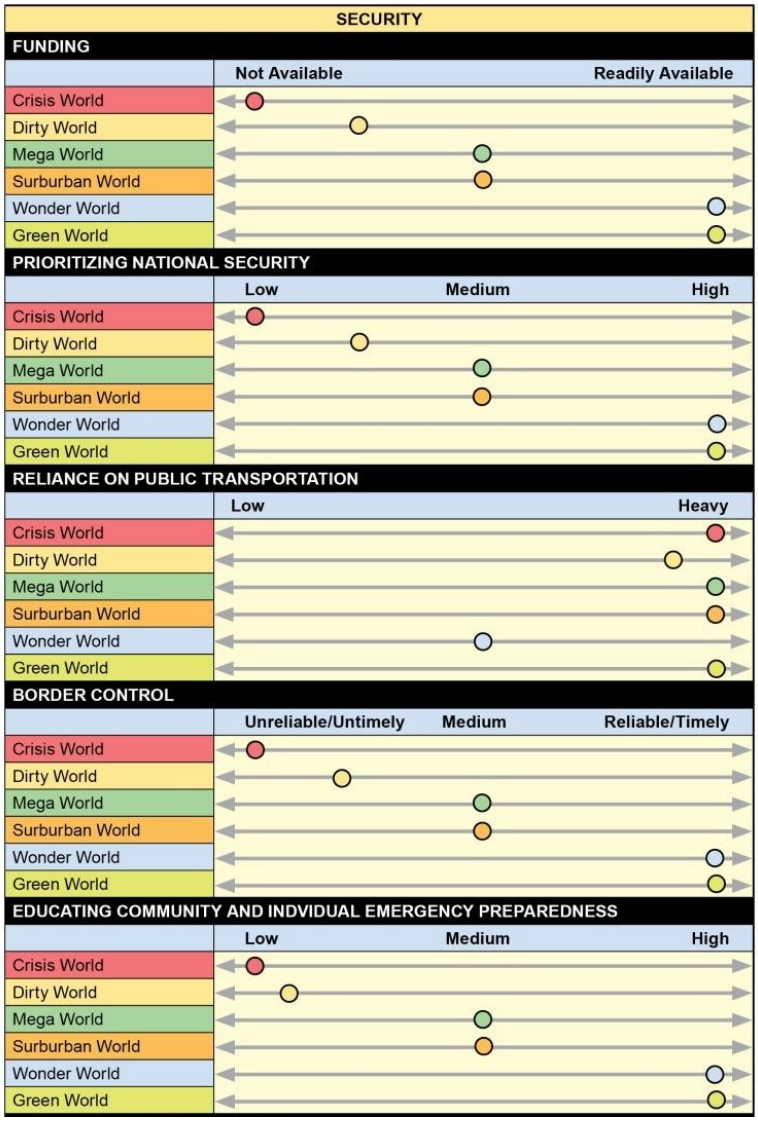

Figure C-4. Drivers for Security Technical Area.

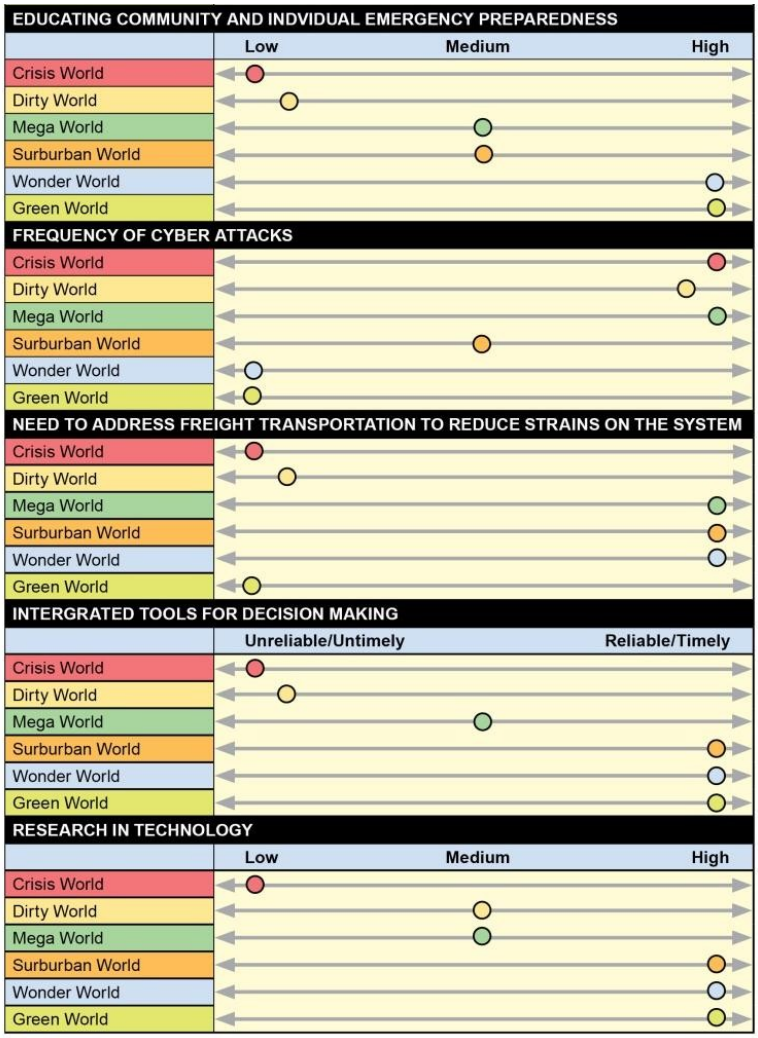

Figure C-4. Drivers for Security Technical Area (Continued).

Crisis World

The following conditions concerning security occur in Crisis World:

- Federal spending on maintaining and preserving highway infrastructure is inadequate and leads to poor security measures. In Crisis World, there are no opportunities to build new transit system or to maintain the existing highway system. The economy is in terrible condition. Only those roads/bridges/pavements with severe damage get fixed. Road-related accidents rise, but there are fewer resources (law enforcement, fire and rescue, emergency medical services, transportation, and towing and recovery agencies) to respond to these accidents. Local, regional, and federal agencies are in operation with minimum resources and are operating inefficiently because agencies lack the resources to coordinate among themselves. Lack of funding leads to no development in integrated transportation systems. Defending and protecting the transportation infrastructure is not a national priority.

- Rise in demand for public transportation leads to faster deterioration of public infrastructure. Rises in gas prices force more people to use public transportation and travel less by private automobiles. With greater demand in public transportation, the United States struggles to maintain the current condition of the roads and especially intercity rail.
- In Crisis World, there are fewer travelers visiting the United States, and security measures are lacking at the border and the airport. Also, the nation has no resources to educate communities and individuals on emergency preparedness. Without proper security measures, the numbers of illegal activities and crimes increase. International trade, freight transportation, transport of hazardous materials decrease.
- A lack of security systems can encourage terrorist to threaten public safety. Terrorist attacks have a detrimental effect on the nation's economy as people just barely survive the life after disaster. Frequent disasters affect people's lives in negative ways.
- Cyber attacks become a big threat to the nation. With lack of measures to defend against cyber attacks, terrorists seize the opportunity to hack into the network system to extract private information, gaining access to control systems and even shutting down the system to gain control of critical infrastructure. For example, hackers can obtain information on the flow of traffic or usage to determine the most optimal target; take control of the entire bridge, railway system, or airport to shut down service; or gain access to surveillance cameras to position bombs and explosives without being caught.
- With time, measures are taken to improve the condition. People change their way of life and find ways to develop integrated tools for decision making regarding protecting the nation's critical infrastructures and implement tighter control around cyber security.

Dirty World

The following conditions concerning security occur in Dirty World:

- The United States attempts to address the inter-agency, inter-operability challenge. In Dirty World, there are some activities to maintain the highway system. The biggest difference between Crisis World and Dirty World is that in Dirty World, multiple agencies collaborate to reduce the amount of resources required to accomplish their goals and missions. Instead of working independently, with scarce resources, agencies choose to integrate and share resources and data to maintain current operations. During this process, there is an attempt to integrate multiple transportation network systems. However, this is still very challenging to implement with low funding.
- With the unemployment rate still high, there is a great demand for public transportation in commuting, and the number of private automobile rides decreases. In contrast to Crisis World, people adjust quickly to their environment and are far more eager to work and are frugal.
- The United States still struggles to maintain the current condition of the roads and especially intercity rails. With less movement of goods, the United States does not see the immediate need to address diverting freight movements to reduce congestions and further deterioration of the highway infrastructure.
- The United States lacks the resources and technology to implement wide-ranging border-control security measures. There are fewer travelers to the United States but cases of

illegal drug manufacturing, trafficking, and smuggling are still prominent. Border control is unreliable and untimely. There is a lack of security measures in place to protect the nation from terrorist attacks and cyber attacks. The United States works diligently to address these issues by promoting research in technology.

- In Dirty World, there is a big movement for more innovative research. Innovative research may include advanced surveillance equipment to monitor suspicious activities, multidimensional x-rays to detect weapons, decision-making tools to optimize rehabilitation of infrastructures, aircrafts that are faster and more reliable, innovative materials that can withstand more force and sudden attacks, design methods to improve the safety and security of government facilities, and an advanced cyber security system.

Mega World

The following conditions concerning security occur in Mega World:

- Economic conditions start to improve in Mega World. There is federal spending on maintaining and preserving highway infrastructure. Traffic-related accidents decrease with better maintenance and management of roadways.
- To reduce the amount of time commuting, people chose to live closer to their workplace. Hence, in Mega World, the population starts to concentrate into 10 mega-regions around the major business districts. Most of the people living farther than 10–15 miles away from the city prefer to travel by private automobiles. But people who live within the city center rely heavily on inter-city public transportation. The United States struggles to find means of public transportation for both the people within the city and people who live 10–50 miles away from the downtown business district. Cities work hard to build systems, such as Chicago's Metra system, that serve people farther away from the city to reduce congestion, pollution, and further deterioration of the roadways. Also, with greater movement of goods into the city, the United States seeks ways to divert or reduce strains on the current transportation system network.
- As large numbers of people congregate in mega-regions, the inter-city transportation system becomes a greater target for terrorist attacks. Terrorist attacks can potentially cause serious economic damage by injuring a large number of people and by disrupting the movement of goods. In response, the government struggles to enforce stronger regulations on traffic safety and border security.
- The United States continues to address the inter-agency, inter-operability challenge. The United States intensely monitors the mega-regions for any suspicious terrorist activities and concentrates most of its resources in these regions. But politicians are still struggling to implement a comprehensive policy to manage all the change in a short amount of period and are inefficient in terms of spending. Multiple agencies monitor terrorist activities, but there is still a lack of inter-agency coordination. However, there is a heightened awareness to coordinate among agencies and improvements.
- The United States is able to create more jobs for its people, and there is enough funding to support innovative research in all areas of transportation. There is a big movement toward research and development of new infrastructure to address the movement of people and goods into the mega-regions. Politicians continue to encourage development of innovative technology to keep up with the change. Research focus might include

developing innovative public-transportation infrastructures within the city to move large numbers of people—technologies such as pod cars, moving conveying belts, elevated or underground capsulated transit tunnels, and man-made waterways for ferries.

Suburban World

The following conditions concerning security occur in Suburban World:

- Suburban World is similar to Mega World. However, improvement of new infrastructure-related technologies and adoption allow people to live farther away from the city. People can live and work wherever they desire. People start to live farther away from the city and become less geographically dependent. It becomes more feasible to work remotely from home, and videoconferencing becomes the norm. This leads to more sophisticated computer systems and networks of these systems.
- Terrorists and hackers train and learn advanced techniques to hack the system and conduct illegal activities in U.S. territories through cyberspace. The government enforces strong security measures around protecting top-secret information and works diligently to develop superior security methods.
- There is adequate federal spending on maintaining and preserving highway infrastructure. Even with distribution of the population, there is still some demand for business travel, and dispersion of people leads to a rise in freight transportation.
- Long-haul shipments become standard. To serve people living in places with no readily available transportation infrastructure, the government seeks to find ways to deliver products to places that do not support large shipments of good. The government may decide to expand and build new roads, underground ways, or railways for the sole purpose of moving heavy loads to some central locations, and divide and make them smaller loads to transport via different transportation mechanism.
- Technological advancement allows the United States to respond better to inter-agency and inter-operability challenge. This leads to superior decision making regarding protecting the national infrastructure.

Wonder World

The following conditions concerning security occur in Wonder World:

- In Wonder World, the United States is going through an economic boom. With enough funding, transportation infrastructure is well maintained and organized. The government focuses heavily on protecting its people and national security. The safety regulation standards are high.
- Enterprise resource planning integrates multiple agencies under one organizational group. People's expectations rise, and they demand immediate attention when rehabilitation is needed. People are also well educated on emergency preparedness. However, people are still somewhat reluctant to sacrifice too much privacy when the government requests personal information for the safety of passengers on public transportation such as rails and airplanes.

- The United States invests heavily in technology. Advancement in technology strengthens border security, and cyber attacks are of no use. Terrorist attacks are also spotted well in advance, and the United States is able to eliminate the source as well.
- In Wonder World, the government continues to encourage research for technological advancement and adoption in the area of transportation infrastructure. There is a smooth transition between multiple modes of transportation and superb control of goods and people that pass through the border. People travel heavily by both individual automobiles and public transportation, but the infrastructure supports the demand, and congestion is minimal. Even with a significant rise in international travelers to the United States, there is a good system in place to monitor and control suspicious activities.

Green World

Green World is similar to Wonder World but is highly regulated.

The following conditions concerning security occur in Green World:

- The United States has a well-managed systematic view of community, energy, communication, and transportation. The federal government has a good strategy for reducing uncertainty about the future and understands the interaction between community, energy, communication, and transportation. Funding is optimized to every sector of the government with reliable decision tools. The government is able to take a more systematic view of the entire network of systems and is more adaptive to the change rather than being reactive. Enterprise resource planning integrates multiple agencies under one organizational group. Also, the government is able to handle the cascading effect of a disaster. With better management of the critical infrastructure networks, public confidence goes up.
- The United States actively manages and regulates to achieve sustainable growth in transportation. A unique characteristic of Green World is that people are very conscience about achieving sustainable growth in every sector. In the city, people become less dependent on vehicles and opt to walk or ride a bike. Most people also prefer to use public transportation as much as possible. Technology radically changes the way transportation develops and grows. However, the federal government actively manages what can be researched and adopted. Technologies that support alternative fuels, zero emission vehicles, and innovative public transit system may be on the top of the list.
- Terrorist attacks become useless due to the advancement in technology. The United States is able to spot and eliminate any suspicious activities well in advance. People live in complete protection and with no fear. The United States tightly regulates immigration and foreign travelers, and there is a decrease in the number of new immigrants and international travelers to the United States. The United States establishes bilateral and multilateral agreements with other nations to tighten border security.
- To protect the people and infrastructures, the government tries to control many aspects of people's lives by either restricting or enforcing certain activities.

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NATURAL-RESOURCE AVAILABILITY TECHNICAL AREA

Overview

The availability and price of natural resources including many forms of energy will significantly affect the ability of the nation to provide highway transportation in the future. Construction, rehabilitation, and maintenance of our highways are greatly dependent upon the availability of energy and other natural resources at an affordable price.

Equipment used to construct, rehabilitate, and maintain our pavements, bridges, roadside, drainage, and traffic services items presently operate on energy nearly 100 percent derived from petroleum or crude oil. Aggregates in combination with asphalt, portland cement, or lime are by far the most commonly used materials in our highway pavements and structures of various types. Metals, ceramics, precious metals, trace elements, and other materials are used in a variety of items for traffic service devices and will be needed for vehicles of the future. Future vehicles will use alternative forms of energy and vehicle control devices of various types. If these natural resources are not available or not available at affordable prices, significant changes will be required in our present-day operations.

Drivers of Natural-Resource Availability

The drivers behind the availability of natural resources fall into these categories:

- Geopolitical conditions.
- Primary energy sources.
- Alternative sources of crude oil and crude-oil substitutes.
- Transportation-vehicle energy sources.
- Binders and aggregates.
- Other raw materials.

Geopolitical Conditions

The availability and price of energy and some raw materials are dependent upon world geopolitics. The availability and price of petroleum have been subject to the existing geopolitical climate since 1973 and the Arab oil embargo. A series of world events, largely out of control of the United States, since 1973 have created periods of volatility with regards to price and availability of various forms of energy and other raw materials.

As the United States becomes more rather than less dependent on the availability of these materials from foreign governments, the more price volatility and availability will become an issue. For example, the United States is more dependent upon foreign crude oil supply now than prior to the 1973 embargo. The United States now imports more finished petroleum products (gasoline, jet fuel, asphalt binder, etc.) than in the 1970s. In addition, more portland cement and more aggregate are imported now than in the 1970s. These trends are expected to continue in the near future.

Primary Energy Sources

Primary energy sources in the world and the United States include petroleum or crude oil, coal and sub-bituminous coal, nuclear, hydro-electric, natural gas, liquids, biofuels, and renewable fuels. Liquid fuels derived from petroleum (and a relatively small percentage from biofuels), natural gas, and coal are presently the three biggest suppliers of our nation's energy needs. Nuclear and hydroelectric are significant contributors. Renewable fuels and biofuels will become more important in the future. Renewable fuels include solar, geothermal, wind, and biomass.

The U.S. Department of Energy's Energy Information Agency provides details of use and projected use to 2035. Reports for NCHRP Projects 20-83(4) and 20-83(7) provide analysis of this and other information. Moderate growth in energy consumption is expected for the United States in the near term. Increased use of imported liquid fuels and strong growth in shale gas production is expected in the next several years in the United States.

Petroleum is expected to be a major supplier of energy for the United States during the next 30 to 50 years. The percent of the total energy obtained from petroleum-derived fuels will likely remain constant or decline over the next 50 years. The price of petroleum-derived fuels will likely increase as compared to other commodities as supply and demand change with time.

Construction, reconstruction, rehabilitation, and maintenance of our highway system are currently very dependent upon petroleum-derived fuels and products. Over 95 percent of energy consumed in the vehicles used for construction, reconstruction, rehabilitation, and maintenance operations of our highways is presently derived from petroleum. Almost 100 percent of our asphalt binders are derived from petroleum. Portland cement and lime production operations are energy intensive. Manufacturing of transportation materials (e.g., asphalt mixtures and portland cement concrete) uses significant amounts of energy. The distance from the aggregate supply to the end use (mostly in urban areas) has increased with time and thus has become very energy dependent and largely dependent upon the availability of liquid fuels.

Alternative Sources of Crude Oil and Crude-Oil Substitutes

Alternative sources of crude oil and crude oil substitutes will be developed over the next 50 years. The rate at which these developments occur will largely be dependent upon the price and supply of conventional crude oil. The extensive oil sand deposits in Canada are presently being developed, and the products are being used in Canada and the United States. Oil shale deposits in the United States are available, and their use will be dependent upon the pricing of crude oil and environmental policies. These deposits are primarily located in Utah, Colorado, and Wyoming.

Coal-to-liquid conversion processes are available, and at present the economics and environmental impacts do not dictate a large-scale development. Carbon dioxide and other emissions associated with the conversion from coal to liquids is a problem that has been identified.

Liquid fuels derived from these alternative sources of crude oil and crude-oil substitutes will be suitable for use in the vehicles that are used to construct, reconstruct, rehabilitate, and maintain our highway transportation network. The conversion from petroleum-derived liquid fuels to fuels derived from these alternatives will be relatively seamless as compared to other changes that the highway industry will face.

As these alternative sources of crude oil and crude-oil substitutes are developed, byproducts and manufactured products need to be investigated as possible binders for construction, reconstruction, rehabilitation, and maintenance of our highway system. A limited amount of research has been conducted with binders derived from oil-sand- and oil-shale-derived products. This research has been conducted both in the laboratory and on the roadway.

Transportation-Vehicle Energy Sources

Transportation uses 28 percent of the total energy consumed in the United States. The transportation sector is heavily dependent upon gasoline, diesel, jet, and bunker fuels. Petroleum-derived liquids supply 98 percent of the fuels presently used for transportation. Seventy percent of all petroleum used in the United States is used as a transportation fuel. The biofuels of gasoline/ethanol mixtures and diesel/biodiesel (fatty-acid methyl ester) mixtures are responsible for most of the 2 percent identified above.

Reduction in transportation fuel use can be achieved by policy and regulation and a change in citizens' behavior patterns that reduce vehicle miles driven and/or reduce congestion. Congestion-reduction measures include time-of-use pricing, telecommuting incentives, intelligent transportation systems, and privately financed highway expansions. Urban and suburban planning in combination with transit systems will also reduce fuel use. Communities that encourage the use of bicycles and walking with the construction of safe facilities also offer some promise for reducing fuel consumption.

Methods to improve the fuel economy of present-day vehicles include reduction in mass, improved aerodynamics, engine technology improvements, transmission technology improvements, vehicle frames, vehicle bodies, suspensions systems, electrical systems, air

conditioning, and exhaust systems. Fuel-consumption standards are established under the Corporate Average Fuel Economy Standards.

Energy sources for transportation vehicles has started to change and will change over the next 30 to 50 years. Some of the technologies and fuel systems that have been developed and will be improved with time include the following:

- Plug-in hybrids (PHEVs).
- Battery-powered electric vehicles (BEVs).
- Compressed natural gas (CNG) (methane and minor amounts of ethane, propane, butane, and pentane).
- Liquid natural gas (LNG) (methane and minor amounts of ethane, propane, butane, and pentane).
- Liquid petroleum gas (LPG) (propane, propylene, butane, and butylenes).
- Coal to liquids.
- Biofuels (ethanol, biodiesel, methanol, butanol, iso-octane, and synthetic diesel)
- Hydrogen fuel cell.

Improved drilling technology that involves the use of multiple horizontal drill shafts from a single vertical well, together with fracturing of the geological formations, has provided economic access to gas and petroleum reserves in tight shale formations in the United States. This technical advancement together with pricing is expected to provide additional U.S. reserves for several decades in the future.

Changes in vehicle-fuel-use patterns and fuel type will impact the state transportation agencies. Revenue generation is likely to be one of the more significant factors. As fuel-use pattern changes, the dependency on petroleum products may be significantly altered. This could potentially result in asphalt-binder shortages. However, some byproducts and manufactured products from these sources of fuel may be suitable as binders. Liquid fuels identified above will be used to fuel vehicles for construction, reconstruction, rehabilitation, and maintenance of highways.

Binders and Aggregates

The majority of materials used for pavements and structures are bound by asphalt, portland cement, and lime and use aggregate as the primary volume filler. Thus, graded aggregate systems, hot-mix asphalt, and portland cement concrete are the primary materials used for construction.

Asphalt binders are nearly 100 percent derived from petroleum (limited amounts of natural asphalts are utilized). Thus, the availability and pricing of crude oil will largely determine the economical availability of asphalt. The manufacture of portland cement and lime are energy intensive, and CO_2 is produced as a byproduct. The availability of an economical energy source is important to the price of these products.

Aggregate sources are available in the United States. The ability to permit new sources and continue to operate existing sources has become increasingly difficult due to regulations and

legal challenges. As a result, aggregate sources have moved farther from their use site, and transportation costs have increased dramatically. The cost of transporting aggregate is typically large as compared to other costs associated with mining, crushing, sizing, and cleaning of the aggregate. Over the last several decades an increasing amount of the U.S. supply of asphalt binder, portland cement, and aggregate is manufactured out of country. This trend is expected to continue over the next 30 to 50 years.

Several alternative binders have and will be considered in the future. These binders include polymers, epoxy, sulfur, lignin, and byproducts or manufactured products from oil sand, oil shale, coal-to-liquid conversions, and biofuels. The availability of these products will depend upon the types of fuels that are used in our transportation vehicles as well as the direction the nation takes for its primary energy sources. Most of the alternative binders identified above are derived from or a byproduct of petroleum or natural gas (e.g., polymers, epoxy, and sulfur).

The construction, reconstruction, rehabilitation, and maintenance of our highway system will require the availability of economical binders and aggregates. The cost of the raw materials used to manufacture these binders as well as the transportation costs associated with the movement of the binders and aggregates to their point of use is important to state transportation agencies.

Other Raw Materials

Raw materials of interest in this driver include iron ore, aluminum ore, trace elements used in metal manufacture, and other elements used for digital electronic equipment including traffic controllers, data transmission systems, etc. Materials that will be used in the manufacture of vehicles that use alternative fuels need to be considered as well (e.g., lithium for batteries).

Steel for reinforcement in structures and pavements and structural steel for bridges are also primary highway materials. Roadside and traffic services devices are manufactured from a variety of materials including steel, aluminum, and ceramics. Trace elements and other materials are used for control systems, data transmission systems, and other digital system uses. Economic availability of these raw materials is important to the construction, reconstruction, rehabilitation, and maintenance of our highway network.

Other Considerations

Policy, regulatory, and legal issues are important to all of the items identified above and could be considered drivers. It is difficult to separate policy, regulatory, and legal issues from price and availability of energy and materials. The state departments of transportation are concerned with the price and availability of materials as well as available revenue to construct, reconstruct, rehabilitate, and maintain the highway transportation system.

World Descriptions

The drivers in the natural-resource availability technical area are present to varying degrees in each world (figure C-5).

Figure C-5. Drivers for Natural-Resource Availability Technical Area.

Crisis World

The following conditions concerning natural-resource availability occur in Crisis World:

- Crisis World is characterized by persistent and long-term crises that range from environmental to economic and social. In Crisis World, the United States lacks the means to adequately respond to challenges, leading to significant changes in the daily status quo for the population.
- The geopolitical condition is constantly unstable and moves from one crisis to another. Primary energy sources are constantly disrupted and high in price, and alternative sources

of crude oil have not developed. Vehicle-energy-source change is underway but underfunded, and as a result slow.
- Binder and aggregate are available at a high price. Depending on the material in question, raw materials are in limited supply.

Dirty World

Dirty World is similar to Crisis World, with the exception that crises related to climate change are less pronounced.

The following conditions concerning natural-resource availability occur in Dirty World:

- The geopolitical condition is more stable and results in less disruption to primary energy sources.
- Some progress has been made in developing alternative sources of crude oil. The rate of development of technology and adoption of alternative energy sources is relatively slow but increasing.
- Binder and aggregate are available, and the price fluctuates with geopolitical pressures. Other raw materials are generally available except in periods of geopolitical pressure.

Mega World

Mega World is presented as a status quo, wherein current trends in terms of economy and population growth are continued. The general population becomes concentrated into 10 major mega-regions.

The following conditions concerning natural-resource availability occur in Mega World:

- The geopolitical condition is mostly stable with some events occurring from time to time that result in disruption to primary energy sources.
- Progress continues to be made in developing alternative sources of crude oil, which reduces the supply and price pressures caused by geopolitical conditions. The rate of development of technology and adoption of alternative energy sources for vehicles has accelerated as more of the population has moved to mega-regions and the use of electrical cars is more feasible.
- Binder and aggregate are available, but transportation of aggregate remains a problem. Price fluctuations in binder and aggregates are reduced as compared to Crisis World and Dirty World. Other raw materials are generally available.

Suburban World

Suburban World is very similar to Mega World with the notable exception being that the population is diffused throughout the country in smaller secondary and tertiary cities.

The following conditions concerning natural-resource availability occur in Suburban World:

- The geopolitical condition is mostly stable with some events occurring from time to time that result in disruption to primary energy sources and other raw materials.

- Progress is made in developing alternative sources of crude oil, which reduces the supply and price pressures caused by geopolitical conditions. The rate of development of technology and adoption of alternative energy sources for vehicles is reduced as compared to Mega World because the population is diverse and electrical cars are not as accepted by the populace.
- Binder and aggregate are available. As a result of urban sprawl, aggregate sources are farther from their end use, transportations costs increase, and hence materials costs increase. Manufacturing plants for hot-mix asphalt and ready-mix concrete are more difficult to permit and are moved farther from the end use of the product.

Wonder World

Wonder World is characterized by faster than anticipated economic and technological development. As a result, there is generalized decentralization of the economy.

The following conditions concerning natural-resource availability occur in Wonder World:

- The geopolitical conditions are stable, and the availability of the nation's primary energy sources and other raw materials is mostly uninterrupted.
- Alternative sources of crude oil become more readily available, and as a result, prices for energy become stable. The rate of development of technology and adoption of alternative energy sources for vehicles is accelerated due to the favorable economy.
- Binder and aggregates are available. However, due to the supply demands, prices are increasing at a rate greater than the general economy indicators.

Green World

Green World resembles Wonder World. The primary difference, however, is that in Green World, there is broad consensus about the importance of sustainability and the need for a green society. This new outlook permeates public-policy decisions and results in more restrictive regulations.

The following conditions concerning natural-resource availability occur in Green World:

- The geopolitical conditions are stable, and the availability of the nation's primary energy sources and other raw materials are mostly uninterrupted.
- A significant movement has been made away from the use of petroleum as primary energy source and as the primary fuel for transportation vehicles. Alternative sources of crude oil are readily available, and renewable energy sources become a more significant portion of our energy supply.
- The supply of asphalt from petroleum is decreased, and alternative binders are used for the construction, reconstruction, rehabilitation, and maintenance of our highway system. This creates a need to make some changes in equipment and requires education of the workforce to use these new materials. Mining and producing aggregates becomes much more difficult, and as a result, the price of aggregates increases faster than general inflation. Permitting of manufacturing facilities for hot-mix asphalt and portland cement types of products becomes difficult, and prices escalate for these and similar products.

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FINANCE AND BUDGET TECHNICAL AREA

Overview

The biggest issue facing the long-term funding and financing of national infrastructure is the inadequacy of the existing framework. This is manifested in two primary ways:

- **Funding sources are not sustainable:** The fuel tax is a weakening proxy for actual use of the roadway system and will lose purchasing power as vehicles become more fuel efficient. The structure of the tax means that revenues are dependent on fuel consumption, placing revenue generation at odds with national environmental goals. Furthermore, technologies are being advanced that would allow passenger vehicles to operate on the roadway system without the need of fossil fuels.
- **Investment processes are not efficient:** Investment decisions are driven by political motives and arcane formulas. Facilities and other infrastructure do not receive funding

based on merit. Federal investment decisions or not necessarily limited to those projects with a national significance.

Drivers of Finance and Budget

The following factors will likely influence the structure of long-term infrastructure funding and financing practices.

The drivers behind long-term infrastructure funding and financing practices fall into these categories:

- Level of domestic spending on transportation.
- Population distribution.
- Adoption of new vehicular technologies.
- National energy policy.
- National financing structure.

Level of Domestic Spending on Transportation

The level of investment in infrastructure, regardless of revenue sources, will have a profound effect on long-term funding and finance. The nation is already facing a crisis in terms of historically low levels of investment. The National Surface Transportation Infrastructure Financing Commission (NSTIFC) found that highway spending in constant dollars, if divided by vehicle miles traveled, has declined by 7 percent since 1988 and has fallen by nearly 50 percent since the establishment of the Highway Trust Fund in the 1950s. From 1980 to 2006, the total number of miles traveled by automobiles increased by 97 percent, and truck miles increased by 106 percent, but lane miles grew by only 4.4 percent.

The federal highway system is reaching the end of its functional life, meaning that more and more is needed to simply maintain existing facilities. Underinvesting in maintenance means that even more investment will be required in the future to ensure that facilities are safe and provide adequate service. Similarly, overinvestment in capacity enhancement presents a similar problem because the added capacity will require maintenance over its lifetime and will require increased funding at the end of its functional life. Domestic spending is thus a balancing act: it is necessary to provide adequate infrastructure today without overburdening future generations with overcapacity.

Population Distribution

The movement toward livable and sustainable communities could potentially reverse trends in suburban development and associated sprawl. In addition, the growth in teleworking is reducing the need for many workers to make daily peak-period commutes, which are the primary driver behind most urban congestion. To what extent will these processes affect the need for investment in highways? What will the effect on revenue be when dependence on automobile travel decreases?

Adoption of New Vehicular Technologies

Within 20 to 30 years, the current crop of new automobiles—those that are coming equipped standard with GPS and other high-tech components—will be obsolete. Furthermore, there is strong evidence that the motoring public of the future will be far more comfortable with the technology currently under development, meaning that their inclusion as standard components in future vehicles is more likely.

What will the next generation of vehicles look like in terms of technology? Will the auto fleet of the future provide a platform for accurately assessing total use of national infrastructure, thus allowing revenue collection to occur and investment decisions to be made in response to actual use?

National Energy Policy

There are two drivers included in this category: fuel prices and national dependency on fossil fuels.

According to the U.S. Department of Energy, fuel prices have declined from the high levels experienced in recent years, but they are anticipated to increase over the next few decades. The price shocks experienced by motorists during the recent high prices led to short-term declines in vehicle miles traveled and sparked renewed interest in hybrid fuel technologies and electric vehicles.

Trends in travel (and associated fuel consumption) and vehicular technology have significant influence over transportation infrastructure funding and finance but are ultimately dependent on the nation's dependency on fossil fuels and the associated price of these fuels. In terms of finance, what are the implications of national efforts to transition away from our dependence on fossil fuels? What taxing and fee mechanisms will be put in place to ensure that national infrastructure is adequately funded?

National Financing Structure

There are three drivers included in this category: public support for user fees, private-sector provision of infrastructure, and reliance on user fees.

In response to pressure on infrastructure budgets, many states and local entities have turned to the private sector to fund, develop, operate, and maintain various forms of public infrastructure. Public-private partnerships are becoming popular for mobilizing private resources to deliver infrastructure solutions in a much faster time frame than the traditional model allows. The key to this success is monetizing infrastructure assets and allowing private entities to draw profit from their investments in improving and managing those assets. Without the ability to turn a profit, there is no incentive for the private sector to participate. To what extent will this trend continue? Will the current reliance on fuel taxes that require legislative action to raise naturally push infrastructure development into private hands? If so, how will systems operate differently if the notion of free travel on highway is removed? Can privatizing public infrastructure help to achieve other policy goals such as sustainability?

World Descriptions

The drivers in the finance and budget technical area are present to varying degrees in each world (Figure C-6).

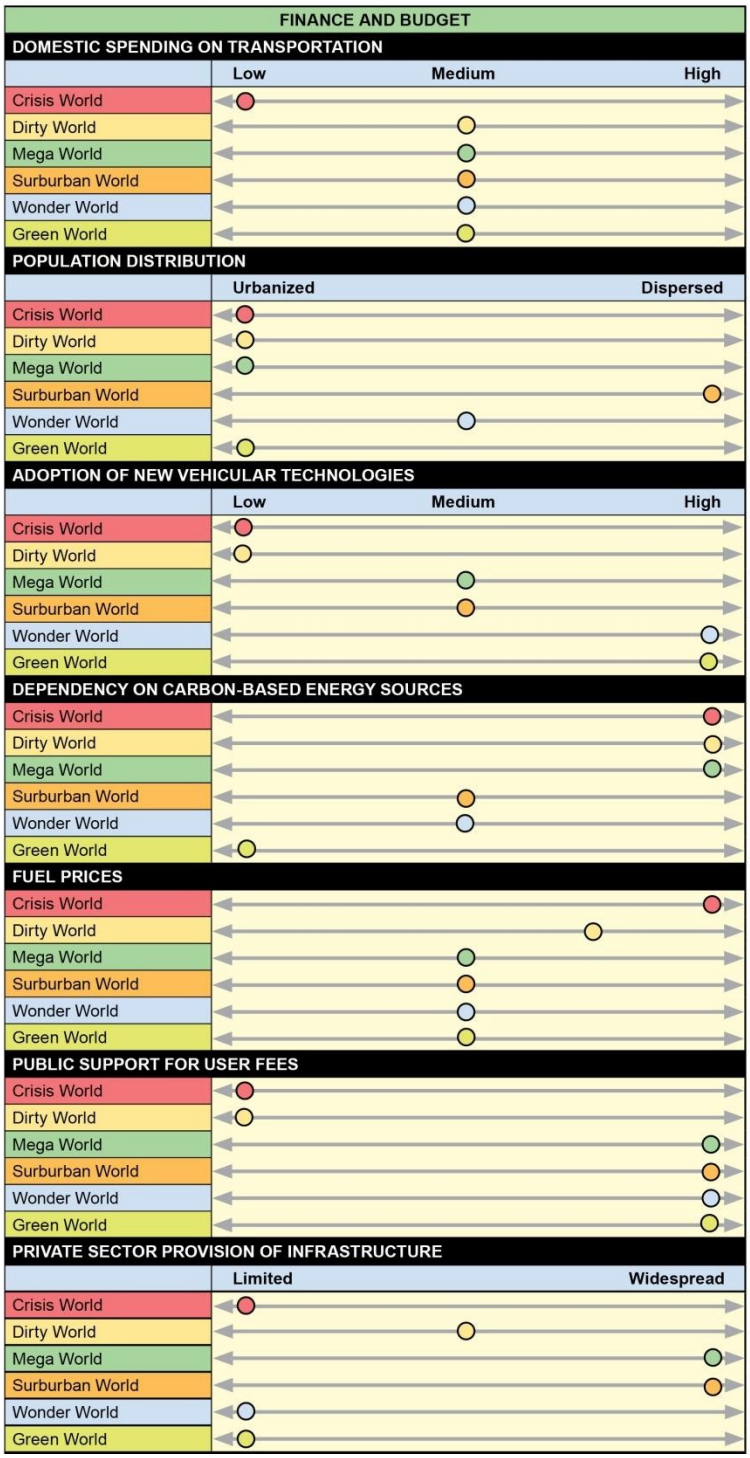

Figure C-6. Drivers for Finance and Budget Technical Area.

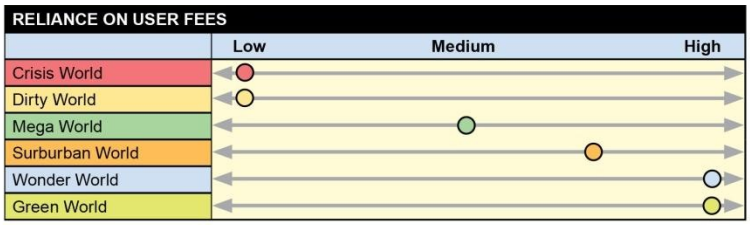

Figure C-6. Drivers for Finance and Budget Technical Area (Continued).

Crisis World

The most pessimistic world, Crisis World, is characterized by persistent and long-term crises that range from environmental to economic to social. In Crisis World, the United States lacks the means to adequately respond to challenges, leading to significant changes in the daily status quo for the population.

The following conditions concerning finance and budget occur in Crisis World:

- Spending on transportation for federal, state, and local governments stays below the historic average of 1.95 percent of GDP. Transportation ranks relatively low in terms of issues of importance for the general population. Due to low levels of investment, infrastructure deteriorates at rates exceeding current projections, but the governmental entities lack the resources to adequately address this. It is also likely that pressure on state and federal budgets from declining revenues provides opportunities for the private sector to participate in infrastructure provision. However, due to high fuel prices and a depressed economy, private involvement is minimal as privatized infrastructure assets is limited to a few highly traveled facilities or to areas with more affluent populations that can afford to drive.
- Fuel taxes continue to provide the bulk of funding for infrastructure development. However, unlike today, existing transportation revenue sources is likely not supplemented by infusions from general funds because those resources are allocated to more pressing uses. In fact, it is likely that any increases in fuel tax rates are directed to other uses such as supplementing general fund revenues, and infrastructure funding itself may even be reallocated. If the crises encountered by the nation are environmental in nature, it is likely that fuel taxes are treated more as a true emissions fee as opposed to a user tax, meaning that revenues are allocated to uses aimed at offsetting environmental damage caused by vehicle travel.
- Fuel tax revenues themselves are depressed due to high fuel prices, which cause motorists to travel less. However, the base of the fuel tax is not as threatened in this world due to the low level of penetration of alternative technologies. The economy remains dependent on carbon, and the United States lacks the resources to address the energy challenge. Fossil fuels continue to be the backbone of national energy policy, but the amount of demand for infrastructure development may decline if the economy is stalled due to perpetual crises.
- Gasoline prices are over $9 per gallon. High fuel prices and an increasing centralization of the U.S. population reduce the need for travel by personal vehicle.

- User fees play little role in funding and financing infrastructure because the population is unlikely to tolerate the imposition of new fees and taxes in the face of perpetual crises.
- There is only limited adoption of new vehicular technologies. The cost of the new technology may be prohibitive to the average user. There are only limited demonstrations of new infrastructure-related technologies, which rely on the private sector for implementation.

Dirty World

Dirty World is similar to Crisis World, with the exception that crises related to climate change are less pronounced.

The following conditions concerning finance and budget occur in Dirty World:

- The funding and finance picture for Dirty World is very similar to that of the Crisis World. The primary difference is that in Dirty World, transportation-related issues are likely to be more prominent in the public's consciousness. That is not to say, however, that transportation is among the most important issues of the day. As in Crisis World, there are a host of other problems, from economic to social, that occupy the public's attention.
- Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP, with the federal government gradually withdrawing. The federal and state governments have difficulty addressing infrastructure needs to due to a lack of resources, meaning that only the most critical infrastructure receives funding for maintenance, and expansion of the roadway network is likely to be minimal if it occurs at all. Any expansion in the roadway network is likely to occur as a result of private investment. Potentially profitable assets are privatized.
- Gasoline prices are somewhat depressed, but world demand continues to push them to over $7 per gallon. Travel by automobile is expensive, meaning that the demand for new infrastructure declines and revenue is constrained.
- As in Crisis World, economic hardship likely precludes the implementation of user fees as a means of addressing infrastructure needs. User fees play little role in funding and financing infrastructure in this world because the population is unlikely to support road user fees given the presence of persistent economic hardship.
- The economy remains dependent on carbon, and the United States lacks the resources to address the energy challenge. There is only limited adoption of new vehicular technologies. The cost of the new technology may be prohibitive to the average user.

Mega World

Mega World is presented as a status quo, where current trends in terms of economy and population growth are continued. In this world, the general population becomes concentrated into 10 major mega-regions.

The following conditions concerning finance and budget occur in Mega World:

- Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP. Investment, management, and control focuses on mega-regions and metropolitan planning organizations.
- Petroleum and carbon fuel remain an important source of fuel. By 2050, gas prices are close to $6 per gallon. Since petroleum remains an important source of energy in Mega World, taxes on petroleum-based fuels remain an important fixture of transportation funding. However, unlike Crisis World and Dirty World, in Mega World alternative vehicular technologies become more prevalent.
- While the adoption of vehicular technologies is limited, the presence of these technologies facilitates a gradual transition to user fees as supplements (if not a full replacements) for the current crop of taxes and fees that are used to fund infrastructure development.
- Unlike Crisis World and Dirty World, continual economic crisis have not depressed the demand for infrastructure because travel in personal vehicles is still affordable. Consequently, demand for the upkeep and maintenance of existing infrastructure and the demand for new infrastructure to better facilitate mobility in the burgeoning mega-regions lead to an increase in privatization at all levels of infrastructure delivery. Privatization may lead to great discrepancies in available transportation: richer areas will have better facilities and services.
- Private entities are tasked with providing for all aspects of infrastructure, but that does not necessarily mean that all infrastructure assets are privatized. Governmental entities still control those assets that are considered of critical importance and still operate and maintain those assets that do not return reliable revenue streams for private entities, namely rural assets.
- Because the population is concentrated in mega-regions, alternative modes do play an increasing role in providing mobility. Consequently, there is still support for funding these modes with revenues generated from road users if other funding sources cannot be identified. However, given that more and more roadway infrastructure is subject to private management, funding for alternative modes becomes more dependent on expenditures from general revenue sources.
- The cost of new vehicular technologies may be large for the average person. There is a difficult chicken-and-egg problem between the speed of development and adoption versus the availability of public support to maximize use of the technology. Without fast adoption, new types of guideways (for personal rapid transit or high-speed rail) will be in only limited use.

Suburban World

Suburban World is very similar to Mega World, with the notable exception that the population is diffused throughout the country in smaller secondary and tertiary cities.

The following conditions concerning finance and budget occur in Suburban World:

- Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP.

- Petroleum and carbon fuel remain an important source of fuel, but alternative fuels account for 18 percent of the transportation market. By 2050, gas prices are close to $7 per gallon.
- The adoption of alternative fuels triggers support for the imposition of road user fees as a supplemental revenue source for funding roadway development.
- In Suburban World, the population is more distributed throughout the country relative to Mega World. Although technology development allows more workers to work out of the home, there is still demand on infrastructure for personal mobility. This demand is difficult to accommodate for alternative modes such as transit and rail, given the more diffuse distribution of the population. Pressure is exerted on federal, state, and local entities to maintain and develop options for passenger vehicle travel. Furthermore, in its support for the imposition of user fees, the public makes demands regarding the use of those revenues, meaning that it will be much more difficult to fund non-roadway-related projects with revenues from roadway-based sources.
- Privatization plays an important role in providing mobility options for travelers, given that investment levels in infrastructure remain low.
- The cost of new vehicular technologies may be large for the average person. There is a difficult chicken-and-egg problem between the speed of development and adoption versus the availability of public support to maximize use of the technology.

Wonder World

Wonder World is characterized by faster than anticipated economic and technological development. As a result, there is a generalized decentralization of the economy.

The following conditions concerning finance and budget occur in Wonder World:

- The population continues to follow current tendencies, with population concentrated in mega-regions.
- Technological advances significantly reduce dependence on fossil fuels, although they are still a crucial source of energy. Alternative fuel sources are rapidly emerging. By 2050, the price of a gallon of gasoline reaches over $7, forcing further innovation and changes in travel behavior.
- Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP (including federal transfers). As a result of improvements in automotive technology and their widespread adoption by the motoring public, there is a fundamental shift in transportation funding away from fuel taxes to usage-based fee systems. These systems allow differential pricing based on a number of different factors to achieve a number of interrelated policy goals.
- As a result of the technological influence, funding decisions with regards to allocation between competing regions and facilities become more empirically based, relying less on the influence of politics. Furthermore, these systems are themselves supported by technology that provides significant benefits to drivers.
- As opposed to other economically constrained worlds, in Wonder World the federal and state governments are more able to provide for basic mobility needs, meaning that fewer public assets must be transferred to the private sector for development and management.

Only the most lucrative of projects, those that would not otherwise be financed with public funds, are developed by the private sector.
- Costs of technologies are reduced from economies of scale. This increases adoption rates for vehicular technology, and government mandates may further speed adoption. New types of vehicles require new guideways; supported transportation facilities may change. Economies of scale may allow public funding of these changes.

Green World

This world resembles Wonder World. The primary difference, however, is that in Green World there is broad consensus about the importance of sustainability and the need for a green society. This new outlook permeates most public-policy decisions.

The following conditions concerning finance and budget occur in Green World:

- Technology allows increased freedom for individuals to live and work where they wish, leading to rapid decentralization. Transportation is improved, with greater transit frequency and more access and mobility.
- Funding and financing in Green World are much like that in Wonder World. Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP.
- Management and planning systems resemble the 1950s and 1960s, with substantial privatization.
- Alternative fuels and green electricity are coming to dominate the transportation market.
- With continually improving automotive technologies, there is a shift to user fees as the primary means of funding infrastructure. Because of the stable economic climate, there is less reliance on private-sector provision of infrastructure.
- Road pricing is aggressively used to achieve various societal and environmental goals. As a result, certain forms of travel are priced significantly higher than other, more sustainable modes. User fees become less of a funding tool and more of a tool for affecting change in travel behavior. Revenue generation is no longer the primary goal.
- Fuel taxes remain in place mainly for the purposes of pricing fossil-fuel-based automotive technologies off of the roadway network; rates are set to make these types of vehicles unattractive to all but the most well off.
- The allocation of revenues from user fees collected from personal vehicles to alternative modes, such as transit and rail, occurs to a much greater extent than in any of the other worlds.
- Costs of technologies are reduced from economies of scale. This increases adoption rates for vehicular technology, and government mandates may further speed adoption. New types of vehicles require new guideways; supported transportation facilities may change. Economies of scale may allow public funding of these changes.

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HUMAN RESOURCES

Overview

The future performance of the transportation system will depend on the quality and quantity of the human resources that design, build, operate, and maintain the various components of that system. The quality and quantity are affected by a number of drivers, the foremost being an appropriate education at all levels—from the roadway maintenance worker to the leadership at corporate and DOT offices.

The transportation sector has historically suffered from an image problem because employment rewards and compensation are not as enticing as those in many competing industries. The performance of the transportation system thus becomes dependent on the quality of the education of the workforce that eventually seeks it as a destination in the transportation sector. Opportunities outside the sector can be a great detractor to getting an appropriately educated workforce and keeping the supply in equilibrium with the demand.

Drivers of Human Resources

The drivers behind human resources fall into these categories:

- Skills required.
- University education
- Technical education
- Trade education
- Transportation skills capacity

Skills Required

Mechanization of future maintenance and construction tasks will demand a more qualified and skilled workforce in general. Robotics can be used to replace some low-level labor. Adoption

within the sector will depend on unions. For a given geographical region, this will naturally depend on right-to-work local and state laws.

University Education

Transportation-sector leaders will be, of necessity, graduates with advanced degrees. The quality of future leadership will depend on competing job opportunities in other sectors of business and commerce.

Technical Education

For middle management, a highly technical education coupled with relevant experience will be a workplace requirement. Many future tasks will be shifted to robotics and other advanced mechanization techniques. This will require highly skilled technical workers for leading controlling and planning operations.

Trade Education

The journeymen of yesteryear will have much higher performance expectations placed on them within the specialized trades that will exist in the future transportation sector. Mechanization of the most basic of tasks can be expected. Skilled (trade-based) workers will be in demand in lieu of an unskilled/untrained labor pool.

Transportation Skills Capacity

The transportation sector often suffers from a poor image and at best is only moderately well paid. The supply and demand of an appropriately educated and focused workforce will depend on other competing opportunities in other industries (such as manufacturing and the service sector) and whether there is a perception that transportation has good long-term sustainable prospects.

World Descriptions

The drivers in the human resources technical area are present to varying degrees in each world (figure C-7).

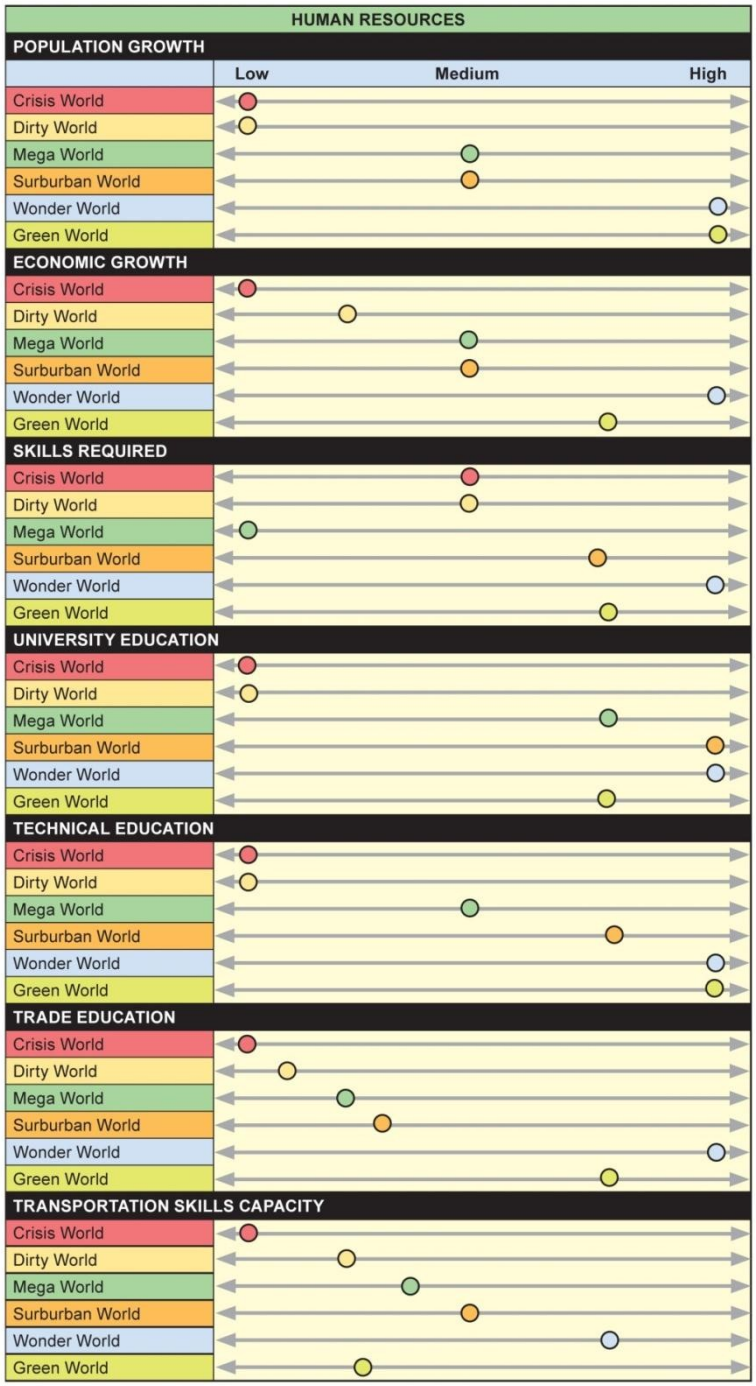

Figure C-7. Drivers for Human Resources Technical Area.

Crisis World

The following conditions concerning human resources occur in Crisis World:

- There is sufficient manual labor, but it is unskilled. Semi-skilled labor is restricted to historic mechanization for road building and maintenance.

- Good engineering students go to mechanical, aerospace, and electrical engineering and end up working primarily in either the defense industries or oil and gas. Transportation and civil engineering students are uninspiring and of mediocre quality at best. This is because transportation engineering is perceived to be the bottom of the heap. Few young adults go to college due to the lack of financial aid.
- Technical education is basically nonexistent because most work is within the military or defense industries. On the other hand, within the military significant on-the-job training is done, and this becomes one limited civilian source of technicians retired from the services.
- Trade education is wanting. Classic carpenters and brick layers abound but are often only semi-skilled. Due to language barriers, they do not have a skill set that is suitably transferable to the transportation industry.
- In Crisis World, demand for good workers far outstrips supply; only sufficient basic labor is available for patch and repair jobs.

Dirty World

The following conditions concerning human resources occur in Dirty World:

- There is sufficient manual labor, but it is largely unskilled. Semi-skilled labor is restricted to historic mechanization methods for road building and maintenance.
- The education of the future transportation worker is also poor. This is because good engineering students go to mechanical, aerospace, and electrical engineering. Civil and transportation engineering students are uninspiring. The good ones get jobs in oil and gas or the (dirty) manufacturing industries. Due to poor salaries, transportation engineering is the bottom of the heap.
- A technical education is also basically nonexistent because most good work is within the manufacturing industries. Some limited community college education exists, but this is not really suited to the infrastructure industries.
- While workers with a trade education may abound, these are restricted to classic carpenters and brick layers and other house-building trades. Moreover, often due to language barriers these workers do not have the right skills transferable to the transportation industry.
- In Dirty World, demand for good workers far outstrips supply; only sufficient basic labor is available for patch and repair jobs.

Mega World

The following conditions concerning human resources occur in Mega World:

- There is an increasing demand for mechanization of most tasks. Technologies and some robotics slowly take hold of the industry, but these are readily learned on the job.
- Many people in the Mega World society have a university education. And while there may be sufficient graduates to choose from, few remain long term in transportation.
- Likewise, many people have a technical education, and there are sufficient technicians that are trained, but too often they are lured away by more attractive opportunities.

- Sufficient skilled workers with a trade education exist, but frequently they also have more attractive alternatives elsewhere.
- In Mega World, the balance between the supply and demand of appropriately skilled transportation workers is in a fragile state of equilibrium because of retention problems.

Suburban World

The following conditions concerning human resources occur in Suburban World:

- There is an increasing demand for mechanization of most tasks. Technologies including robotics slowly take hold of the industry, but these are readily learned on the job.
- There is a broad base of well-educated people. This includes a sufficient supply of university graduates to choose from, but few remain long term in transportation.
- Similarly, there is a sufficient number of technically educated workers, and while well trained many technicians are lured away by more attractive opportunities in higher-paying private-sector jobs.
- Sufficient skilled workers with a trade education exist, but frequently they also have more attractive alternatives elsewhere.
- In Suburban World, the balance between the supply and demand of appropriately skilled transportation workers is in a fragile state of equilibrium because of retention problems.

Wonder World

The following conditions concerning human resources occur in Wonder World:

- Wonder World is a place that demands a highly skilled workforce. In part this is because there is a high demand for robotic mechanization of most tasks. Technologies rapidly take hold of the industry due to the private-sector profit motive. This requires a highly specialized, educated, and trained workforce.
- With a university education there are great jobs opportunities for all branches of engineering, and there is a good selection pool of graduates. Long-term opportunities are attractive; thus, employees are loyal to the industry. University education is regularly funded through industry-sponsored cadetships.
- Para-professional super-technicians with a focused and specialized technical education also require ongoing specialized on-the- job-oriented training, mainly to deal with robotic technologies.
- Persons with a trade education are the technicians of yesteryear. These workers too are necessary to operate the robotic equipment.
- All of the jobs within the transportation sector are well paid—it is cool to be in the transportation industry, from bottom to top. Since the rewards are commensurate with the job demands and satisfaction, the demand for skilled transportation workers at all levels is in balance with the supply. And while there is a high demand for transportation-specialized skills, this is met by an eager workforce. Consequently, the industry enjoys long-term stability.

Green World

The following conditions concerning human resources occur in Green World:

- There is a high demand for job skills due to the clean-green robotic mechanization of many tasks; however, this is in conflict with a school of thought that considers manual labor as superior and more green. Heavy-handed government intervention requires a balance of the two, largely to appease the green union workers.
- Great job opportunities exist for university graduates in all branches of engineering; there is a good selection pool of graduates. But there is a stigma associated with working in the non-green industries; this reduces the potential labor pool by at least one-third. University-educated green education programs are heavily subsidized by the federal government.
- Para-professional super-technicians also require specialized job-oriented education. This is the preferred and pragmatic level of education for a green society.
- There remains a good number of minimum-wage labor jobs, plus more elite unionized renditions as well.
- It is not really cool to be in the transportation industry—it has too big a carbon footprint from the past; a stigma lingers. There is a high demand for mid-level transportation-specialized skills, and this is met by an eager indoctrinated green workforce. But the industry remains unsettled and volatile; it does not enjoy long-term stability.

COORDINATION TECHNICAL AREA

Overview

The development and maintenance of a highway transportation system are dependent upon a number of partnerships among the state transportation agencies, other public agencies, and private industry. Coordination of these various entities is crucial to both the short-term and long-term success of a transportation system.

As the world changes, so do the demands on our transportation systems. Intermodal facilities to handle passenger and freight movement will become more important in the future. Related government agencies and industries will supply more and more technology that will be adopted by the highway mode of transportation. Policy and regulatory agencies will play an increasingly more important role in the design, delivery, and maintenance of highway transportation facilities.

Drivers of Coordination

The drivers behind coordination fall into these categories:

- Intermodal considerations.
- Related industries.
- Policy and regulatory agencies.

Intermodal Considerations

Intermodal transfer of passengers and freight between highways, water, rail, air, pedestrian, bicycle, and transit will become more important as population increases and as the mega-regions of the country are developed. The demand for water to highway and rail has increased dramatically over the last several decades as the United States becomes more dependent on off-shore manufacture of consumer and industrial goods. Rail transportation has become important for commodity shipments of energy-generating materials as well as construction materials and agricultural products. Water transport on our nation's rivers, coastal canals, and oceans is vital to the movement of goods in this country.

A substantial number of intermodal transfer facilities will be constructed over the next 50 years. The construction of these facilities and the planning for the impacts on the modes of transportation involved in the facility needs coordination and partnerships to be formed among the various agencies involved in the facilities. These facilities will impact multiple agencies and jurisdictions. This coordination is vital to the overall success of our transportation system.

The expansion of intermodal transportation has the potential to both increase the volume of traffic (near the intermodal centers) and decrease the volume of traffic (on the overall highway system). In addition, this development may also cause more competition to occur between competing modes of transportation for scare financial resources.

Related Industries

A large number of industries are vital to the development and maintenance of our transportation system. A substantial number of industries receive and ship substantial volumes of freight. These industries rely on just-in-time delivery and shipment as well as uncongested highways to produce economical products. These freight-dependent companies are vital partners to state highway agencies.

Advanced highway and transportation technology as well as applied engineering products will be generated by related industry and academic institutions and state highway agencies. The rapid development and implementation of this technology can only be accomplished by partnerships that allow coordination between the private sector, academics, and state highway agencies.

Engineering consultants are, now more than ever, involved in the design and construction of highway systems. These firms are retained as consultants directly to the highway agency or as part of contractor-headed design/build teams. Consultants play an increasingly more important role in the delivery and maintenance of highways. The quality of projects is dependent upon the quality of the consultants.

Contractors and material suppliers will continue to play a vital role in the construction and maintenance of the highway system. Coordination with these groups is critical for obtaining quality work at reasonable costs. Partnerships with private industry, academic institutions, consultants, material suppliers, and contractors will facilitate the continued development of highway systems.

Policy and Regulatory Agencies

Policy and regulation associated with environmental issues have been discussed in the environmental area of this report. Coordination among all of the parties responsible for environmental policy and regulation is crucial to project success.

Other agencies and industries impact the delivery and maintenance of the highway system. For example:

- States receiving federal dollars for highway projects are subject to Federal Highway Administration rules and regulations.
- Fair trade and labor regulations greatly affect the delivery of highways.
- Coordination with utility companies, railroad owners, and right-of-way purchase continue to be major obstacles encountered in the timely delivery of highway projects. Coordination with these entities is vital to the successful completion of projects in a timely manner.

World Descriptions

The drivers in the coordination technical area are present to varying degrees in each world (figure C-8).

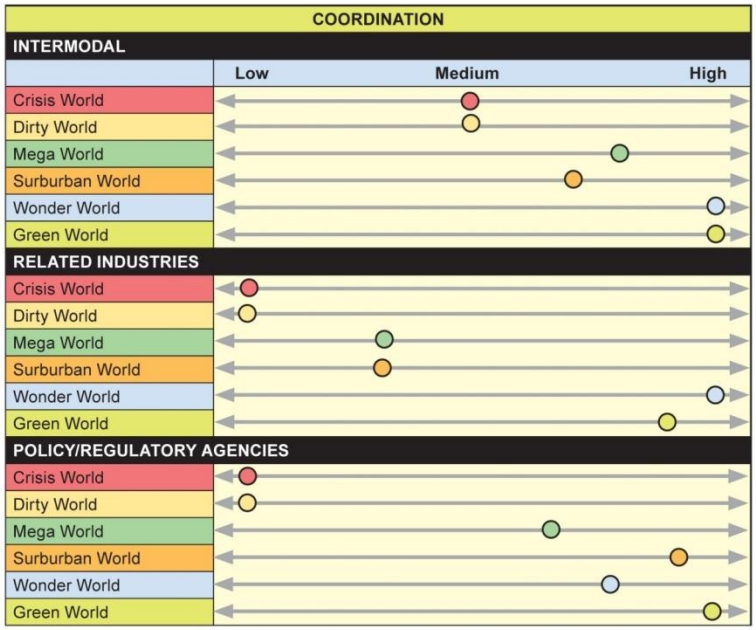

Figure C-8. Drivers for Coordination Technical Area.

Crisis World

Crisis World is characterized by persistent and long-term crises that range from environmental to economic and social. In Crisis World, the United States lacks the means to adequately respond to challenges, leading to significant changes in daily status quo for the population.

The following conditions concerning coordination occur in Crisis World:

- Policy and regulation associated with public agencies are alternatively strict and relaxed because the nation is unable to meet regulatory standards due to the economy. State transportation agencies must devote considerable resources to policy and regulation changes and requirements.
- Coordination with utilities and railroad agencies remains a problem. Right-of-way purchase is difficult. Intermodal passenger and freight facilities are slow to be established due to funding for alternative modes of transportation.
- Related industries are unwilling to cooperate due to intellectual property issues, research funding is very limited, and funding is not generally available for development and implementation activities. Engineering consultants, material suppliers, and contractors are not willing to assume risks.

Dirty World

Dirty World is similar to Crisis World, with the exception that crises related to climate change are less pronounced.

The following conditions concerning coordination occur in Dirty World:

- Policy and regulations associated with highway transportation are steady, and change is slow because climate change and financial constraints are present. State transportation agencies must devote considerable resources to policy and regulation changes and requirements.
- Coordination with utilities and railroad agencies remains a problem. Right-of-way purchase is difficult. Intermodal passenger and freight facilities are slow to be established due to funding for alternative modes of transportation.
- Related industries are unwilling to cooperate due to intellectual property issues. Research funding is very limited, and funding is not generally available for development and implementation activities. Engineering consultants, material suppliers, and contractors are not willing to assume risks.

Mega World

Mega World is a status quo, where current trends in terms of economy and population growth are continued. The general population becomes concentrated into 10 major mega-regions.

The following conditions concerning coordination occur in Mega World:

- Policy and regulation associated with highway transportation are steady, and change in environment-related issues is noticeable.
- Coordination with utilities and railroads is improving. Right-of-way purchase is difficult in some jurisdictions and relatively easy in other jurisdictions. Intermodal transfer facilities for both passengers and freight are developed due to an improved economy and the urbanization of the population.

- More cooperation is experienced with related industries, and funding for research increases in both the public and private sectors. Engineering consultants, materials suppliers, and contractors are more willing to assume risks.

Suburban World

Suburban World is very similar to Mega World, with the notable exception that the population is diffused throughout the country in smaller secondary and tertiary cities.

The following conditions concerning coordination occur in Suburban World:

- Policy and regulation associated with highway transportation are steady, and change in environment-related issues is noticeable.
- Coordination with utilities and railroads is improving. Right-of-way purchase is difficult in some jurisdictions and relatively easy in other jurisdictions. Intermodal transfer facilities for both passengers and freight are somewhat slow to develop because populations are not concentrated.
- More cooperation is experienced with related industries, and funding for research increases in both the public and private sectors. Engineering consultants, material suppliers, and contractors are more willing to assume risks.

Wonder World

Wonder World is characterized by faster than anticipated economic and technological development. As a result, there is generalized decentralization of the economy.

The following conditions concerning coordination occur in Wonder World:

- Policy and regulation associated with the environment are steady, and progress is being made as new technologies are introduced and the economy is financially strong.
- Coordination with utilities and railroads is good, and right-of-way purchase is no longer a problem. Intermodal transfer facilities for both passengers and freight are rapidly developing.
- More cooperation is experienced with related industries, and research funding is high in both the public and private sectors. Engineering consultants, materials suppliers, and contractors are taking risks to introduce technology.

Green World

Green World resembles Wonder World. The primary difference, however, is that in Green World there is broad consensus about the importance of sustainability and the need for a green society. This new outlook permeates public-policy decisions and results in more restrictive regulations.

The following conditions concerning coordination occur in Green World:

- Policy and regulation associated with the environment are evident and affect the state transportation agencies' business model. Progress is being made as new technologies are developed, deployed, and introduced rapidly, and the economy is financially strong.

- Coordination with utilities and railroads is good, and right-of-way purchase is no longer a problem. Intermodal transfer facilities for both passengers and freight are rapidly developing.
- More cooperation is experienced with related industries, and research funding is high in both the public and private sectors. Engineering consultants, materials suppliers, and contractors are taking risks to introduce technology.

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REGULATIONS AND POLICIES TECHNICAL AREA

Overview

The transportation policy process is composed of several overlapping layers, and long-term changes in the relationships between these layers will largely drive changes in the policy development and implementation process. These layers include:

- **The federal government:** The federal government exerts influence in a number of different ways, but primarily through funding. Federal fuel taxes provide the largest piece of transportation-related funding for federal programs, and requirements for the receiving of those funds constitute a significant form of leverage for the federal government. Numerous requirements, such as those related to design standards and safety applications, are part of various federal funding programs. The federal government also applies regulatory pressure through an assortment of methods. For example, the federal government is responsible for issuing CAFE standards that dictate the required fuel efficiency of domestically sold automobiles. The federal government is also responsible for establishing many of the planning practices that must be adopted at the state and local level of government. For example, NEPA requires the rigorous evaluation of alternatives.
- **State government:** In terms of transportation policy, the states are responsible for allocating revenues received from federal grants (pursuant to the various restrictions placed on the use of those funds) and allocate funding from their own revenue sources, comprised usually of fuel taxes, vehicle registration fees, and occasionally some portion of vehicle sales taxes and general sales taxes. Some states also receive revenues from tolling enterprises.

- **Local government (including cities and counties):** In most states, county and local entities are subordinate to the state government but wield their influence in terms of transportation policy in the form of planning for their particular areas.
- **Quasi-governmental entities:** Quasi-governmental entities refer to toll and mobility authorities and other related entities, such as transit entities, that operate infrastructure assets as a private enterprise but are still subordinate in some form to elected officials. Their influence in transportation policy is continually increasing as pressures on federal and state transportation budgets increase opportunities for tolling and pricing.
- **The private sector:** Purely private entities might also be involved in the provision of transportation infrastructure, either through the development, maintenance, or operation of facilities. Transit entities may also be included in this category because they are generally responsible for the operation of public infrastructure assets but are not elected (though they are generally accountable to elected entities). A metropolitan planning organization (MPO) may also fit into this category because they are comprised of both elected and appointed officials. Although MPOs are generally not responsible for the operation of infrastructure assets, they are the initiating entity for most metropolitan planning efforts.

Drivers of Regulations and Policies

The drivers behind regulations and policies fall into these categories:

- Level of spending on transportation.
- Federal regulatory presence.
- Planning processes.
- Population distribution.
- Penetration of roadside and in-vehicle technologies.
- Reliance on user fees.
- Private-sector provision of infrastructure.

Level of Spending on Transportation

The overall level of funding in infrastructure development will affect the ability of various entities to influence transportation policy among the states and various local entities. For example:

- If less federal funding is available, then the federal government will have less influence over how policies will be enacted and how infrastructure development will occur.
- In the absence of federal funding, states will make efforts to address needs on their own. The continued development of mileage-based user fees by states like Oregon, Minnesota, and Nevada in the absence of federal action to address future funding shortfalls is testament to this.
- Furthermore, as funding from state-based resources has dwindled, local entities have made strides to implement local tolling initiatives to address local infrastructure needs. The increased reliance on tolling by various entities in the Dallas-Fort Worth area

illustrates how strained funding at the state level drives subordinate jurisdictions to seek their own revenue sources.

Federal Regulatory Presence

In recent years there has been a trend among state and local entities to lobby for increased federal assistance in the form of funding but with increased flexibility in how to use those funds. If this trend continues, it is likely to have numerous impacts on transportation policy. Increased flexibility in the use of funds reduces the ability of the federal government to exert influence over policy. A removal of political influence from the funding allocation process may also decrease the influence of the federal government over transportation policy.

This is not to say that all funding decisions are beholden to parochial interests. At the federal level, allocation formulas based on numerous metrics including population and traffic volumes are used to determine where funding should be allocated. However, even with this level of empirically based funding, there is a growing consensus that funding decisions need to be based even more on actual need, with little to no influence from political prerogatives. Moreover, there is an increasing demand for system accountability through measureable improvements in performance or strict cost-benefit ratios.

Planning Processes

Planning is generally a bottom-up process, with local entities such as MPOs taking the lead in determining how infrastructure will be developed, with state and federal entities incorporating these plans into larger regional, state, and national plans. State and federal entities are generally unwilling (if not unable) to develop infrastructure without the approval and subsequent cooperation of local entities.

However, it is possible that in the future, state and federal entities may have more influence over how local entities plan and deploy infrastructure. This influence would most likely be manifested as the allocation of revenues toward desired means. For example, the federal government has recently made sustainability and the enhancement of livability as key goals of transportation-related policy. The vision for such development includes mixed-use communities that incorporate employment, housing, entertainment, and shopping within denser and more transit and pedestrian friendly land use applications. To encourage the inclusion of sustainability as a goal in local planning efforts, state and federal authorities could make funding available for planning practices and land use that fulfills this goal.

It is likely that influence from state and federal entities over planning processes such as this would remain incentive based because it would be difficult to impose more coercive or mandatory measures.

Population Distribution

Transportation policy is likely to be influenced by long-term development patterns. According to data from the U.S. Census Bureau, metropolitan areas have accounted for the majority of growth in the United States in the past 50 years. In 1950, urban areas accounted for 56 percent of the

nation's growth in population. That number increased to almost 70 percent in 1970, 77 percent in 1990, and 80 percent in 2000.

If development continues to be concentrated in urban areas, then policies oriented around enhancing mobility options within these areas and enhancing connectivity to other urban areas are likely to be dominant. This will increase the influence of urban entities and states with concentrated, urban populations. However, if development patterns change such that population growth occurs in a more diffuse pattern, then the influence of rural interests is likely to increase.

Penetration of Roadside and In-Vehicle Technologies

The penetration of technologies that allow the accurate assessment of national road use could influence a number of policy-related aspects. These technologies include both roadside infrastructure and in-vehicle systems that may rely on the use of satellite signals such as those from the Global Navigational Satellite System (GNSS).

If such systems gain widespread penetration, then it might enable the collection of empirical data that can be used to measure system performance and in cost/benefit analyses for infrastructure investment. These data would likely be used in the allocation of funding. Decisions on which states and local entities are to receive funding would be less likely to be dependent on elected officials.

Reliance on User Fees

The reliance on user fees to fund transportation infrastructure will influence transportation policy from the perspective that revenues from user fees are generally dedicated to the infrastructure from which they are drawn.

It is important to make a distinction with regard to the current transportation funding and financing system and its primary revenue source, the fuel tax. While the fuel tax was initially levied at the federal level as a usage tax, it is gradually becoming a less appropriate proxy for road use. Fuel taxes are excise taxes levied on the physical amount of fuel purchased for use, meaning that vehicles with lower fuel efficiencies pay less per mile traveled (or, in other words, pay less per use). Consequently, for the purposes of this document fuel taxes are not considered to be a true road user fee. In order for a fee mechanism to be classified as a true user fee in this document, all vehicles subject to the fee must be charged the same amount if they use the same amount of roadway resources. Under this definition, fuel taxes and vehicle registration fees would not be considered true road user fees, but tolls and mileage-based fees would.

In the event that user fees are implemented on a large-scale basis, such that travel on federal highways is priced in lieu of fuel taxes, it is likely that motorists would make demands on how the revenues are used. Revenues generated under the fee system would go to maintain and enhance the facilities where the revenues were generated or within the area of those facilities. User fees are less likely to be allocated for purposes served by general fund revenues than tax revenues. Furthermore, the deployment of user fees for transportation infrastructure by state and local entities might also reduce the need for federal aid, thus reducing the influence of the federal government.

Private-Sector Provision of Infrastructure

The role of the private sector in infrastructure provision could have significant impact on transportation policy. Reduced investment by governmental entities in transportation will provide new opportunities for the private sector to participate, assuming that requisite enabling legislation is present and the market is sufficient to generate revenues.

An enhanced role for the private sector could shift the government's focus on infrastructure from funding and financing to protection of the public interest through regulation. Another possibility is that private funds would be used to leverage existing public funding for the faster delivery of infrastructure-related projects. In this case, the private sector would require a return on its investment, meaning that the projects being invested in would have to generate revenue streams.

World Descriptions

The drivers in the regulations and policies technical area are present to varying degrees in each world (figure C-9).

Crisis World

Crisis World is characterized by persistent and long-term crises that range from environmental to economic to social. In Crisis World, the United States lacks the means to adequately respond to challenges leading to significant changes in the daily status quo for the population.

The following conditions concerning regulations and policies occur in Crisis World:

- Spending on transportation for federal, state, and local governments stays below the historic average of 1.95 percent of GDP. This is the only world in this document where investment falls below 1.95 percent of GDP. All other worlds maintain the traditional funding level.
- From a policy perspective, Crisis World presents a challenge for decision makers because transportation-related issues rank extremely low in terms of importance, and the federal government is preoccupied with other crises and cannot devote resources to transportation. As a result, state and local entities are responsible for the planning and execution of transportation-related policy. The focus for these entities is primarily on preserving existing infrastructure because the national economic climate precludes the need for enhanced mobility through capacity expansion. However, it is likely that funding will not be sufficient to maintain existing infrastructure, and resources will be dedicated to facilities with the most volume, such as those located in dense urban areas or priority corridors linking major urban areas or areas necessary for economic activity such as major ports. This means that the condition of low-volume, low-priority infrastructure will deteriorate at an accelerated rate. With this deterioration, the chances of catastrophic events, such as bridge collapses, are likely to increase.
- Strong emphasis is on developing urban-area mega-regions and MPOs. Many roadways and bridges fall into disrepair, and there are limited transit options. Transportation systems outside mega-regions and metropolitan areas decline.

Figure C-9. Drivers for Regulations and Policies Technical Area.

- With the shift in focus to preservation, it is likely that federal, state, and local entities will, when possible, enact systems aimed at managing use. However, these systems will be very limited due to strong public resistance to the imposition of user fees.

Consequently, it is likely that cordon pricing systems could be implemented in extremely high-volume urban areas.

- The public strongly opposes increases in existing transportation-related fees such as fuel taxes and vehicle registration fees.
- The movement of freight, which places a much higher burden on roadway assets than passenger travel, is likely to be confined to high-priority corridors. Significant volumes of freight therefore shift to other modes, most notably rail. However, the state of the national economy means that demand for freight mobility is muted.
- The federal government has a substantially weakened regulatory presence but likely still attempts to exert influence over state and local transportation policy through the allocation of funding. However, declining fuel tax revenues severely restrict the federal government's ability to do so. Federal investment in transportation is lower than historic averages, further reducing the influence of the federal government. States are likely to still require these federally administered funds and continue to adhere to federal guidelines, but the overall lack of funding greatly reduces the influence of the federal government in these affairs.
- Technology adoption is low in Crisis World, meaning that traditional planning and prioritization practices remain in effect. This, coupled with shortages of transportation-related funding, enhances the role of politics in making transportation-related funding decisions. Revenues are not necessarily allocated based on true need. As a result, system efficiency is greatly reduced.
- The role of the private sector in Crisis World is minimal, not because there is not a need but because there is depressed travel on the part of the motoring public. As a result, the potential profitability of highway facilities is reduced, and economic conditions depress the rapid urban and suburban development that has induced recent private investment in added capacity. Due to a lack of revenue potential, the private sector does not have an increased role in the preservation and maintenance of existing infrastructure. Without new funding mechanisms, only high-demand toll roads are privatized.

Dirty World

Dirty World is similar to Crisis World, with the exception that crises related to climate change are less pronounced. This means that environment-related catastrophes such as major flooding, drought-related fires, and hurricanes are less frequent, allowing governmental entities to direct more attention to non-emergency issues.

The following conditions concerning regulations and policies occur in Dirty World:

- Strong emphasis is on developing urban-area mega-regions and MPOs. Some roadways and bridges fall into disrepair, and the public has limited public transportation options. Transportation systems outside mega-regions and metropolitan areas decline.
- Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP. Federal investment in transportation is slightly increased in Dirty World relative to Crisis World and elevated to historic levels, but the influence of the federal government in transportation policy is still minimal compared to other worlds. In Dirty World, the federal and state governments have difficulty addressing infrastructure needs due to a lack of resources, meaning that only the most critical

infrastructure receives funding for maintenance, and expansion of the roadway network is likely to be minimal, if it occurs at all. Responsibility for infrastructure planning is dispersed among the states and local entities.

- The influence over policy, in terms of directing revenues to desired project types or modes, is reduced to simply allocating revenues to where they are most needed. Politics still play a role in determining where the need for maintenance and upkeep is greatest, but issues related to mobility, connectivity, and sustainability are not likely to factor into these decisions. Any expansion in the roadway network is likely to occur as a result of private investment, with only potentially profitable assets being privatized. Policy is therefore limited in this respect to ensuring that assets are managed in the public's best interest.
- User fees play little role in funding and financing infrastructure in this world because the population is unlikely to support road user fees given the presence of persistent economic hardship. It is possible that road user fees could be implemented in the most high-volume areas and corridors, but the use of these pricing systems is not far reaching. Traditional revenue sources, such as fuel taxes and vehicle registration fees, remain in place, but due to economic hardship, they are not likely to be increased by the amounts necessary to adequately maintain existing infrastructure and expand capacity.
- Roadside and in-vehicle technology deployment is low, meaning that new mechanisms for assessing need and guiding planning processes are still absent. Revenues are not necessarily allocated based on true need. Transportation policy thus remains dependent on the influence of politics, and system efficiency is not maximized in terms of targeting investment.
- The key in terms of policy for both Dirty World and Crisis World is maintenance and preservation. Connectivity and mobility objectives do not play a major role in allocating revenues among competing assets.

Mega World

Mega World is a status quo world, where current trends in economic and population growth continue. The general population becomes concentrated into 10 major mega-regions.

The following conditions concerning regulations and policies occur in Mega World:

- Population growth and development occur mostly in a few urban-based mega-regions. The economic hardships of Crisis World and Dirty World are not present, so the federal government is able to better invest in transportation infrastructure and maintain a stronger regulatory presence. This world is, in effect, the status quo, where the structure of transportation policy largely resembles that of today.
- Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP.
- One major difference between Mega World and today is the importance placed on developing infrastructure within and between mega-regions. Investment in facilities in rural regions is based on their ability to provide connectivity, in terms of both person and freight movement, between mega-regions as opposed to their ability to provide transportation services for those living in these areas.

- The cost of new vehicular technologies may be large for the average person. As a result, the market for additional development is likely to be minimal, keeping technology penetration low.
- The increased penetration of roadside and in-vehicle technologies enables the use of road user fees that directly gauge use of infrastructure. Most vehicles are factory equipped with some form of satellite navigation system. These systems allow a more direct assessment of where travel is occurring and where investments need to be targeted. The influence of politics is reduced in making funding decisions but is still present. However, the efficiency of the transportation network is improved over Crisis and Dirty World, even if only marginally.
- The increased prevalence of road user fees restricts the federal (and to a lesser extent state and local) government's ability to allocate funding based on political motivations. Investments are made more efficiently since infrastructure needs can be assessed from a cost/benefit viewpoint.
- Investment, management, and control focuses on mega-regions and MPOs. The increased demand placed on infrastructure in these rapidly expanding mega-regions strains transportation budgets at all levels, prompting an increase in the reliance on private-sector provision of such assets. Private entities are tasked with providing for all aspects of infrastructure, which may lead to discrepancies in available transportation: richer areas will have better facilities and services. That does not necessarily mean that all infrastructure assets are privatized. Governmental entities still control those assets that are considered critically important and still operate and maintain those assets that do not return reliable revenue streams for private entities, namely rural assets.

Suburban World

Suburban World is very similar to Mega World, with the notable exception that the population is dispersed throughout the country in smaller secondary and tertiary cities.

The following conditions concerning regulations and policies occur in Suburban World:

- Transportation policy in Suburban World is much like that of Mega World in that it represents a continuation of today's policy climate. However, the main difference between Suburban World and Mega World is that the population is much more dispersed. The power of urban areas in setting policy and obtaining funding for regional projects is reduced by the growing power of rural areas. The ability of rural areas to obtain additional funding and influence policy is greatly aided by the development of technology-intensive road user fees, a development that is facilitated by the increased penetration of roadside and in-vehicle technologies.
- Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP.
- Agencies rely on user fees for transportation funding.
- Private entities play an important role in providing mobility options for travelers. However, this role is reduced relative to Mega World since the distribution of the population reduces the potential profitability of many infrastructure assets.

- Technology allows increased freedom for individuals to live and work where they wish, leading to rapid decentralization.
- The cost of new vehicular technologies may be large for the average person. There is a difficult chicken-and-egg problem between the speed of development and adoption versus the availability of public support to maximize use of the technology.

Wonder World

Wonder World is characterized by faster than anticipated economic and technological development. As a result, there is a generalized decentralization of the economy.

The following conditions concerning regulations and policies occur in Wonder World:

- Population continues to follow current tendencies with population concentrated in mega-regions. Planning for new infrastructure is centered on sustainability with a heavy focus on investment in urban areas. Transportation is improved (greater transit frequency, more access, and greater mobility). Investment, management, and control focuses on mega-regions and MPOs, with the federal government focusing on interregional transport in cooperation with privatized transportation organizations.
- Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP (including federal transfers).
- Agencies rely heavily on user fees for transportation funding.
- There are two primary characteristics of Wonder World in terms of transportation policy that set it apart from the other scenarios discussed in this report. The first is that due to the rapid penetration of roadside and in-vehicle technologies, there is a vast road user charging system in place for the complete funding and financing of national infrastructure. Costs are reduced from economies of scale that increase adoption rates for vehicular technology. All new vehicles are equipped with mandatory satellite-based navigational equipment that also serves to gather information related to road use. The acceptance of these technologies by the general motoring public is greatly enhanced relative to today because future generations of drivers will have much more exposure to these types of technologies and have fewer, if any, privacy concerns.
- Fuel taxes may still be in place as a funding mechanism, but they mainly act as an emissions charge as opposed to a road user fee. Because of this road user fee system, the power to influence transportation policy through the appropriation of revenues is diminished. Funding decisions are based primarily on need, and the road user fee system accurately assesses need based on information gathered from all vehicles on the roadway.
- The second characteristic of Wonder World is that the federal government, although reduced in fiscal influence due to the prevalence of road user fees, has heightened regulatory influence, particularly with regard to setting sustainability standards for municipal development. This is likely to occur through the use of incentives, with the federal government setting aside funding for the implementation of infrastructure that suits desired national policy goals. Wonder World is characterized by a general consensus on the part of society to develop in a sustainable manner, and this vision is best achieved through the imposition of federal standards. Individual cities and counties are

still able to develop based on a local vision, but the overall development framework is set by the federal, and to a lesser extent state, government.

Green World

This world resembles Wonder World. The primary difference, however, is that in Green World, there is broad consensus about the importance of sustainability and the need for a green society. This new outlook permeates most public policy decisions.

The following conditions concerning regulations and policies occur in Green World:

- Technology allows increased freedom for individuals to live and work where they wish, leading to rapid decentralization. Transportation is improved (greater transit frequency, more access, and greater mobility).
- Spending on transportation for federal, state, and local governments stays at the historic average of 1.95 percent of GDP.
- Public support moves to user fees.
- Alternative fuels and green electricity come to dominate the transportation market.
- Costs are reduced from economies of scale that increase adoption rates of vehicular technology. Government mandates may speed adoption.
- New types of vehicles require new guideways. Supported transportation facilities may change. Economies of scale may allow public funding of these changes.
- The primary difference between Green World and Wonder World is that the federal regulatory presence is heightened, and development is concentrated in urban areas that are deemed to be more sustainable. Development in suburban and rural areas is discouraged because these are not deemed to be in line with sustainable development practices.

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DEMOGRAPHICS TECHNICAL AREA

Overview

Understanding demographic changes is important to identifying future travel patterns and the corresponding demand on the system. Demographics is defined as measures of population size and basic dimensions of the population (age, gender, and race), and changes in these measures over time and space. Socio-demographics is a broader area that also includes socio-economic aspects such as household size, income, and employment status, which can also affect travel characteristics.

From the perspective of assessing the future demand on the transportation system, spatial aspects that include a geographic dimension are additionally important. For instance, broad demographic measures will help describe interstate and intrastate travel demand, but the geographic dimension is needed to examine regional demand characteristics, including differences in urban and non-urban travel patterns.

While socio-demographic factors influence travel behavior, travel behavior can, in turn, influence the socio-economic and demographic profile of a city or region. Increases in congestion levels on the local transportation network will drive up the price of the most accessible property, influencing the demographic characteristics with respect to different accessibility levels.

Attributes of the travel environment—the supply of roads and transit, congestion levels, prices, distribution of destinations, and accessibility by non-motorized modes—are spatial variables that combine with socio-economic variables to influence travel demand. Advanced applied regional models, such as those used by metropolitan planning organizations to forecast long-range demand, are generally suitable for measuring the effects of demographics incorporating spatial and infrastructure supply factors. However, these models are typically more of an extension of the current conditions rather than forecasts of alternative scenarios representing a full range of demographic possibilities.

The U.S. Census Bureau provides detailed projections of the national population through 2050.[39] Here are some of the trends:

- 111 million people will be added to the population of the United States by 2050, from 308 million in 2010 to 419 million in 2050, an average of 2.8 million people per year.
- In 2050, the U.S. population will be significantly larger, older, and more ethnically diverse than today.
- The average male and female life expectancy will increase by approximately seven years to 81.2 for males and 86.7 for females in 2050.
- The population over 60 years of age will rise from 16 percent in 2010 to 26 percent in 2050.
- Hispanics, both U.S. born and immigrants, will represent 25 percent of the population by 2050.

[39] U.S. Census Bureau Population Projections. http://www.census.gov/population/www/projections/. Accessed July 7, 2011.

- Net migration (i.e., immigration minus emigration) is estimated to be 996,000 in 2025 and 1,097,000 in 2050.

Population distribution can follow several alternative scenarios. One possibility is the mega-region model, which suggests 80 percent of the population, economic activities, and jobs will be centered in mega-regions, defined as connected communities via a complex network of economic, infrastructure, and geographic relationships. An alternative model is one of greater decentralization, where growth will occur in small towns, suburbs, and second-tier cities outside the mega-regions. The 2010 census provides support for the notion that while central-city populations have grown in the last decade, most of the growth has occurred in suburbs surrounding the growing cities of the South and West.

DRIVERS OF DEMOGRAPHICS

For the purposes of addressing the six worlds concerning the impact of demographics on future travel demand,[40] six key socio-demographic drivers were selected:

- Population growth in relation to the spatial characteristics of urban form.
- Rate of assimilation of Hispanic households.
- Changes in household size and dependency ratios.
- Aspirational consumption and auto ownership.
- Effects of ubiquitous connectivity.
- Labor force related to assimilation.

One frequently discussed demographic trend—aging population—is absent from this list. In the 30–50 year timeframe for this study, the Baby Boomer generation will not be a factor, even though people will be living longer. The overall age profile of the population will be more homogenous without this large population group.

Population Growth in Relation to the Spatial Characteristics of Urban Form

This driver recognizes that population growth will occur in absolute numbers with some variation according to external influences, and will have differing impacts on the highway system depending on urban form. For example:

- High levels of population growth in densely developed areas will create greater concentrations of highway demand.
- Low levels of population growth in more dispersed urban forms will create lower concentrations of demand.

Rate of Assimilation of Hispanic Households

By 2050, Hispanics will represent one in four of the U.S. population. According to census data, Hispanics have larger households, fewer vehicles per household, and fewer new-model vehicles. U.S.- and foreign-born Hispanics also make more trips per household than non-Hispanics. There

[40] Johanna Zmud. Presentation on NCHRP 20-83(06). U.S. Department of Transportation Forum on Transportation and Demographic Trends from the 2010 Census, May 23, 2011.

are differences, however, in the trip-making characteristics of U.S.-born Hispanics, who over time mirror non-Hispanics in travel behavior. Foreign-born Hispanics have more households with no vehicles, make more transit trips and fewer auto trips, and carpool and walk more. Therefore, as the rate of assimilation of immigrant Hispanic households increases, there will be more auto trips and fewer alternative mode trips.

Changes in Household Size and Dependency Ratios

Household size is no longer shrinking; in 2000, the average household size was 2.59, and in 2008 it was 2.62. A number of factors affect this change: aging parents moving back in with their children, young adults living with parents, and more children in the household due to higher fertility rates among immigrants, particularly in Hispanic households. Children in the home are a significant indicator of daily trip making, with the age of children influencing the interaction with parent trip making. Households with children make significantly more trips than those without children, and drivers in Hispanic households with children make more trips than drivers in non-Hispanic households.

Over the next 40 years, as the Baby Boomer generation passes and the age of the population becomes more homogenous, age will continue to influence driving. Whites will continue driving into their senior years, and will prefer driving over walking or using transit due to perceived safety and security concerns. Hispanic women, particularly older Hispanic women, do not drive as much as non-Hispanic women, but this trend is expected to change as Hispanics assimilate into the U.S. population.

The impact on trip making by household is evident: larger household size and higher dependency ratios (i.e., the ratio of youth and elderly in the population) will lead to greater trip making. However, larger household sizes should lead to fewer overall households, resulting in fewer household trips because fewer households exist. The impact on traffic demand at the facility level, therefore, is highly dependent upon the demographic characteristics (such as household size) within individual regions.

Aspirational Consumption and Auto Ownership

Global consumption patterns have demonstrated that as GDP reaches $4,000 per capita, auto ownership per capita doubles. In conditions of economic prosperity, people choose to use their money to purchase cars even if they have become accustomed to transit as their primary mode of travel. Additionally, there is a high rate of unlicensed drivers in the immigrant populations, drivers who purchase very inexpensive vehicles that can be abandoned if necessary with little financial penalty. As immigrant populations assimilate and economic conditions improve, auto ownership increases, which leads to a rise in the use of the highway system.

Effects of Ubiquitous Connectivity

As the rate of technology use accelerates, generational use of information and communication technologies (ICT) can provide an indication of future use of the transportation system. For Generation Y or Millennials (age 18–29), 93 percent are online for most of their daily activities, 81 percent use wireless technologies, and 72 percent use social networking. While the use of ICT is growing in other age profiles, it is not nearly as much of a part of daily life as it is for

Generation Y. There are four possible effects of ubiquitous connectivity from a travel behavior perspective:

- **Substitution:** decrease in travel demand.
- **Complementarity:** generation of new trips.
- **Modification:** change of temporal/spatial characteristics of travel.
- **Neutrality:** no impact.

The effects of ICT on travel are unknown; a study conducted prior to Google®, Facebook®, and the iPhone® suggests there is little support for trip substitution as a result of ICT use and more support for complementarity travel, or generation of new trips. This implies that ICT is not a substitute for travel but a facilitator of more travel. Others believe that the pervasive use of ICT by younger generations will ultimately lead to more telecommuting in the future, despite recent trends that have been flat. For the purposes of future scenario development, we assume that ubiquitous connectivity will lead to a reduction in travel demand as Generation Y and generations that follow have lives that are highly integrated with ICT.

Labor Force Related to Assimilation

Over time the **w**orking age (age 16 years and older) will shift from 63 percent of the total population in 2005 to 58 percent of the total population in 2050, with a higher rate of the working population representing immigrants and their descendants. Hispanics will become an increasing share of workers: 14 percent of working-age population in 2005 is Hispanic, compared to a projected 31 percent in 2050 (for white workers: 68 percent 2005 to 45 percent in 2050). Among the different categories of jobs, Hispanics work in service jobs more than any other category (26 percent in 2008). From a travel perspective, a number of these jobs require multiple daily trips (house to house to house or site to site to site). These employment trends will continue into the future with varying impacts depending upon the level of assimilation.

Other Possible Drivers

The six drivers described above were used for the development of the future world descriptions, which are presented later in this report. A number of other possible socio-demographic drivers can impact travel demand to varying degrees:[41]

- Drivers related to population size and growth:
    - Population size and growth rate.
    - Changes in life expectancy by gender and race/ethnicity.
    - Changes in births among foreign-born and native-born women.
    - Changes in mortality over time with emphasis on older populations.
    - Internal net migration between regions.
    - International net migration estimates by region.
    - Population distribution.

[41] *Draft Interim Report.* NCHRP 20-83(02): Effects of Socio-Demographics on Travel Demand, December 22, 2010.

- Drivers related to geo-demographics of population size and growth:
    - Regional economics, such as job growth.
    - Low- and high-growth metro areas including those that serve as immigration entry ports.
    - Regional changes in household formation.
    - Moves of minorities to suburbs over the past decade.
    - Residential location choice.
- Drivers related to household structure and composition:
    - Household type or structure.
    - Dependency ratios (percentage of youth and elderly in population who are dependent on other members of household for transportation).
- Drivers related to household-based economic activity:
    - Household education level, occupation, and income.
    - Women and changes in gender work activities.
    - Changes in disposable income.
    - Differential patterns in expenditures by ethnicity/race/foreign-born households.
    - Changes in expenditures due to household changes.
- Drivers related to cultural and social diversity:
    - Rate of acculturation of foreign-born populations.
    - Composition of foreign-born households.
    - Differences in linguistically isolated household and other households' travel patterns.
- External factors intertwined with socio-demographics:
    - Urban form.
    - Investment in infrastructure.
    - Undeveloped land zones for residential use.
    - Changes in growth of higher-density housing.

World Descriptions

The drivers in the demographics technical area are present to varying degrees in each world (figure C-10).

Crisis World

The following conditions concerning demographics occur in Crisis World:

- This is the most pessimistic world, characterized by a world under persistent crisis. The United States is under considerable stress, and there are significant resource constraints.

- Population growth is lower than projected, and population distribution is more centralized, though land use is mixed and unplanned.
- With low economic growth and crisis conditions with respect to the environment and resource availability, acculturation and assimilation of ethnic populations are low, resulting in fewer auto trips and more ridesharing and alternative mode use where available. Conversely, lower assimilation may lead to more work trips within the workforce.
- Economic conditions will also influence auto ownership, resulting in lower travel demand. Economic conditions coupled with low acculturation rates will lead to higher household sizes, resulting in more trip making per household.
- Low technology adoption fails to appreciably reduce demand.

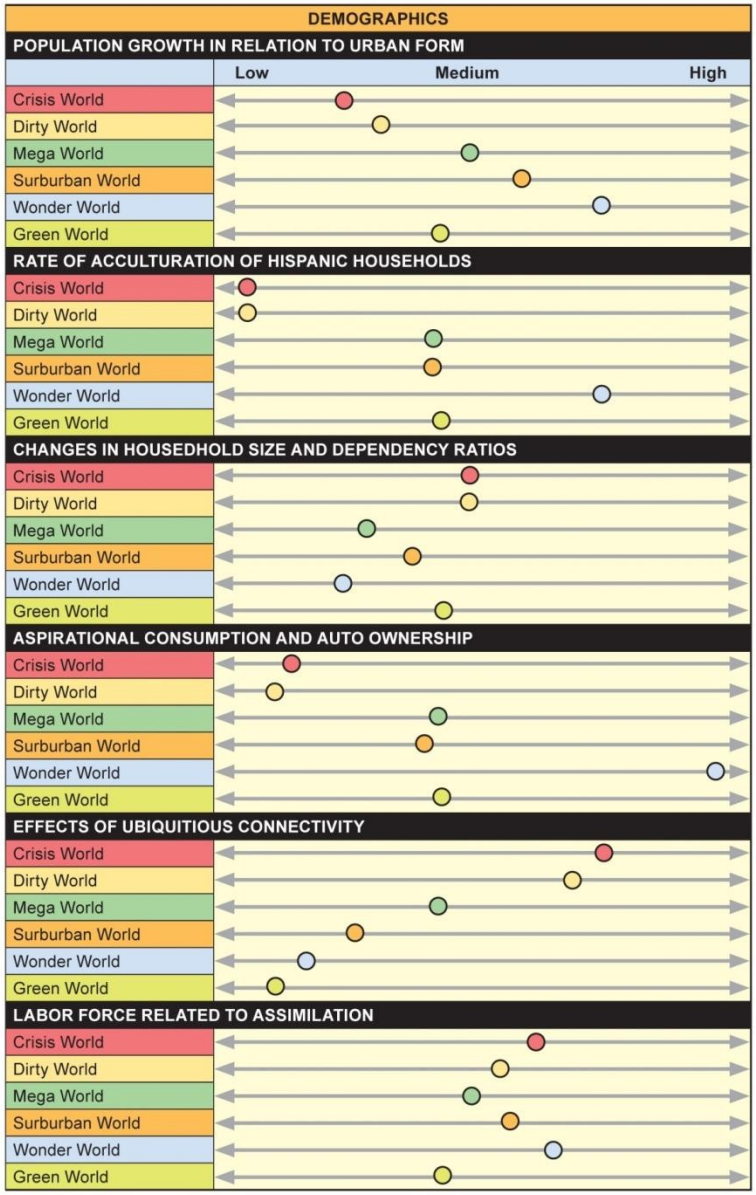

Figure C-10. Drivers for Demographics Technical Area.

Dirty World

The following conditions concerning demographics occur in Dirty World:

- Similar to Crisis World, Dirty World represents a world under pressure with slow economic growth and technology adoption. However, climate change is slower, allowing a world that is still under pressure to change using traditional techniques and approaches.
- Population growth is lower than projected, and population distribution is more centralized; land use is mixed and planned.
- With low economic growth, acculturation and assimilation of ethnic populations are moderate, resulting in more auto trips and less ridesharing and alternative mode use compared to that in Crisis World. Conversely, lower assimilation may lead to more work trips within the workforce.
- Economic conditions limit auto ownership and thus result in lower demand.
- Economic conditions coupled with low acculturation rates lead to higher household sizes, resulting in more trip making per household.
- Low technology adoption fails to appreciably reduce demand.

Mega World

The following conditions concerning demographics occur in Mega World:

- Mega World finds the future of the United States as a continuation of current trends.
- Economic and population growth is anticipated to be consistent with most likely projections, with slow adoption of new transportation funding mechanisms.
- Population is increasingly concentrated in the 10 major mega-regions, with a tendency toward urban concentration and mixed land use.
- With moderate economic growth, acculturation and assimilation of ethnic populations are moderate to high, resulting in more auto trips and less ridesharing and alternative mode use. However, alternative mode use rises as higher densities in the mega-regions support transit accessibility. Moderate assimilation may lead to fewer work trips within the workforce.
- Economic conditions lead to moderate growth in auto ownership and thus result in higher highway demand.
- Economic conditions coupled with higher acculturation rates lead to lower household sizes, resulting in fewer trips per household.
- Moderate technology adoption makes inroads in reducing demand.

Suburban World

The following conditions concerning demographics occur in Suburban World:

- Suburban World is the second business-as-usual world next to Mega World. The primary difference is that Suburban World has a decentralized environment where technology allows people to live in a variety of settings that best suit their preferences, such as suburbs, small towns, and second tier-cities.

- With moderate economic growth, acculturation and assimilation of ethnic populations are moderate to high, resulting in more auto trips and less ridesharing and alternative mode use. Decentralized destinations support the increase in auto use.
- Moderate assimilation may lead to fewer work trips within the workforce, but with dispersed activities the reduction may be offset by travel of greater distances.
- Economic conditions lead to moderate growth in auto ownership and thus result in higher highway demand.
- Improved economic conditions coupled with higher acculturation rates lead to lower household sizes, resulting in fewer trips per household.
- Moderate technology adoption makes inroads in reducing demand by allowing dispersed development but with technology-enhanced alternatives to traditional travel.

Wonder World

The following conditions concerning demographics occur in Wonder World:

- The first of two positive worlds, Wonder World is characterized by better-than-expected economic growth, rapid technology development, and a decentralized population that is growing at rates higher than anticipated.
- With high economic growth, acculturation and assimilation of ethnic populations are high, resulting in more auto trips and less ridesharing and alternative mode use. Decentralized destinations support the increase in auto use.
- High assimilation may lead to fewer work trips within the workforce, but with dispersed activities the reduction may be offset by travel of greater distances.
- Economic conditions lead to high growth in auto ownership and thus result in highway demand at the higher end of the scale.
- Improved economic conditions coupled with higher acculturation rates lead to lower household sizes, resulting in fewer trips per household.
- High technology adoption makes inroads in reducing demand by allowing dispersed development but with technology-enhanced alternatives to traditional travel.

Green World

The following conditions concerning demographics occur in Green World:

- The second of two positive worlds, Green World is characterized by rapid economic growth, accelerated technology development and adoption, and high population growth.
- With a push toward a more sustainable, green society, a strong regulatory framework directs land development to dense urban form and exerts greater social and economic control. Demographic factors may have less of an impact on travel behavior under a highly regulated environment.
- With high economic growth, acculturation and assimilation of ethnic populations are high, but resources are oriented toward reduction in personal auto use by emphasizing alternative mass transit modes and system pricing. High assimilation may lead to fewer work trips within the workforce.

- Economic conditions lead to high growth in auto ownership and thus result in highway demand at the higher end of the scale, but demand is tempered by regulations.
- Improved economic conditions coupled with higher acculturation rates lead to lower household sizes, resulting in fewer trips per household.
- High technology adoption makes inroads in reducing demand by allowing technology-enhanced alternatives to traditional travel.

CUSTOMER NEEDS AND EXPECTATIONS TECHNICAL AREA

Overview

The term customer expectation encompasses many dimensions. A person's expectations are based on their perception of the service being provided, the provider (usually a particular company), and the industry in general.[42] The expectation is formed through past experience of the person and others the person interacts with. In some instances, it may serve as a proxy for customer satisfaction. If a service provider—be it a transportation system, a utility provider, or the local grocery store—feels it is meeting customer expectations, it may infer that the customers or system users are also satisfied, but that is not always the case. Other organizations have been more proactive in managing customer expectations and relating that to superior customer satisfaction. This has not typically been the case in the transportation sector, but it has been evolving over time.

In 1993, a recommendation from Vice President Al Gore's National Performance Review team began a revolution in customer service for the federal government. It was followed with Executive Order 12862 from President Clinton for Setting Customer Service Standards.[43] The order directed federal agencies to survey their customers to determine the types of services people wanted and what they were getting. He set a goal for the government to deliver service equal to the best in the business.

The exercise began with benchmarking federal agencies against the best in the business. The benchmarking determined which businesses, public and private, were doing the best job of customer complaint resolution, understanding the gap between the agencies own performance and the expectation of the customer, and what actions were used to close the gap. Studies focused on why a particular business was the best and how those actions could be implemented in the federal agency.

On April 27, 2011, President Obama furthered this by issuing a related executive order, 13571, requiring executive departments and agencies of the federal government to enact Customer Service Plans to address how the agency will provide service in a manner that streamlines service delivery and improves the experience of its customers.[44] Moreover, this plan is to be

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[42] Ray Miller. Customer Expectation vs. Customer Needs. http://www.customerservicemanager.com/customer-expectations-vs-customer-needs.htm. Accessed May 25, 2011.

[43] William J. Clinton. Presidential Documents. Archives, September 14, 1993. http://www.archives.gov/federal-register/executive-orders/pdf/12862.pdf. Accessed May 25, 2011.

[44] Barack Obama. Executive Order 13571—Streamlining Service Delivery and Improving Customer Service. Government Printing Office, April 27, 2011. http://www.gpo.gov/fdsys/pkg/DCPD-201100288/pdf/DCPD-201100288.pdf. Accessed May 25, 2011.

published on each agency's website. In doing this, President Obama recognizes that advances in technology and service delivery systems in other sectors raise customer expectations that the federal government at least meet, if not exceed, the same expectations that customers have with the private sector.

Drivers of Customer Needs and Expectations

The drivers behind influencing or affecting customer needs and expectations fall into these categories:

- Implementing agency.
- Privatization of transportation assets.
- Acceptance of user fees.
- Technological advances.
- Globalization.
- Movement toward sustainability.
- Involvement in decision making.
- Privacy.
- Overall transportation opportunities.

Implementing Agency

In recent years the public's expectations of the government's ability to provide quality services have diminished. However, there has been an effort to improve service among governmental agencies and to adopt more of a business-minded approach, as noted earlier. Because expectations are formed based on previous experiences, shifts in the public's expectations of governmental agencies' abilities to efficiently and effectively implement projects may be slow to change. Therefore, the agency implementing a particular transportation project or even the agency charged with transportation planning may affect the customers' expectations. Historically, customers have had higher expectations of the private sector than the public sector.

Privatization of Transportation Assets

Numerous reports document the rising cost of transportation investment.[45,46] The limited ability to expand congested corridors results in environmental degradation, increasing fuel and delay costs, and frustration among the traveling public. More fuel-efficient vehicles and rising prices for construction materials further erode the purchasing power of the fuel taxes that are currently collected. Over time, the gap will become wider. Couple this with are policies that encourage alternative-fuel vehicles, reduced reliance on foreign oil, and limited domestic production and exploration, yet continue to tax fuel as a funding mechanism for the nation's transportation system. The results are policies that are at odds with each other.

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[45] U.S. Senate Committee on Environment and Public Works. *The Need for Transportation Investment*. Testimony, Washington, D.C., 2009.

[46] American Association of State Highway and Transportation Officials. *Report on the Long-Term Financing Needs for Surface Transportation.* Washington, D.C., 2007.

Many state and local governments are exploring options and opportunities to augment their fuel tax revenue shortfall or even find replacement mechanisms. A small number of demonstration programs and pilot projects have investigated the viability of alternative methods of transportation funding including various forms of pricing or assessing fees based on mileage. Others have looked to the private sector as a means of sharing infrastructure costs. As with any major shift in policy, there is apprehension associated with the unknowns. Some research has been conducted on the public's attitudes and acceptance of various new forms of project delivery mechanisms, most notably privatization.

The literature suggests that private-sector involvement will be crucial in meeting the nation's transportation needs if we continue with the current funding systems. However, because transportation, primarily highway transportation, has been perceived as free by the motoring public since the construction of the interstate system, there is an understandable aversion to pay extra in the form of tolls or other pricing mechanisms. Specific public concerns related to private sector involvement include:

- Facility undervaluation—fear that government owners of a facility will not get a fair price for the facility.
- Use of upfront payments—concern that large upfront payments by concessionaires will not be dedicated to transportation uses.
- Length of concession—in many current concession agreements, lease terms range from 50–75 years with consideration of some longer terms.
- Noncompeting clauses—the public is afraid that these clauses, used to protect the private investment, will prevent improvements being made to the system.
- Perceptions that the public sector could raise as much money as the private concession deal—belief that a public agency ought to be able to structure similar financing proposals.
- Limited opportunities for public participation and outreach—the competitive nature of the agreements requires more documentation to be kept confidential until after award of a contract. This is counterintuitive to the current practice of developing transportation projects.
- Private-sector interests to maximize revenue that result in toll rates that do not maximize facility use—concern that the private-sector operator will gouge facility users.
- Cherry picking of profitable projects—belief that only the most profitable projects will interest the private sector, thus leaving marginal projects undeveloped and unfunded.
- Public control related to contract terms—fear that the public has no control once a contract is signed.
- Windfall revenues—seemingly unfair profiteering by the private sector.
- Operation and maintenance—apprehension that the facility will not be properly operated and maintained.
- Environmental standards—belief that the private sector will attempt to circumvent the environmental process and/or not be held to same environmental stewardship standards.
- Eminent domain—fear of the private sector having powers of eminent domain.

- Labor issues—concern over hiring and labor issues.
- System needs—concern that other system needs will go unmet.[47]

Privatization is unfamiliar in the realm of transportation investment, and it is reasonable to expect public skepticism. The list above identifies some of the areas that will need to be addressed. There is a need for an objective analysis of all viable approaches. Florida and New Jersey are taking this approach.[47] Moreover, privatization is not limited to the delivery of infrastructure projects but also can include maintenance and operations of facilities. Public acceptance will be impacted by the government and the private sector's ability to answer these questions adequately.

Acceptance of User Fees

With private-sector involvement, there is a reasonable expectation that the private sector must seek a mechanism to achieve a return on its investment. In many cases, this is accomplished through a user fee. The term user fee, as used in this context, is differentiated from the traditional gas tax, which is also a user fee. In this regard user fee refers to payment for the use of a particular facility or mode or access to an area. The fee may be for travel on a transit system or access to an area such as a central business district or for travel on a roadway, in the form of a toll charge. The public's expectation of and acceptance of user fees will vary depending on circumstances and the level of service received. To date, there has been limited acceptance of user fees. There has been considerable public resistance to implementing pricing on existing roadways to pay for reconstruction or to manage demand. However, as conditions deteriorate and traditional funding for maintenance decreases, the public may become more accepting of user fees.

Technological Advancements

The public's expectation and their response to increased and decreased involvement of the private sector in providing transportation options will vary based on the other factors relevant in society in the next 50 years. It is unclear whether our future need for transportation infrastructure will increase or decrease. There are two alternative views of transportation in the future, and the environment is the driving factor.[48] The two views are that:

- Technology will improve vehicle efficiency (fuel, highway, and vehicle).
- Private vehicles will be obsolete; planning (regulation) and social change will drive this.

Customer expectations will also be reflective of advances in other technologies, notably communications and information. Advances in the fields in recent decades have increased the public's appetite for and expectation of these services and the providers of these services. Continued advances, no doubt, will impact the transportation industry and the public's expectations. If technological advances in other areas such as communications are meeting

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[47] Ortiz, I. B. "Protecting the Public Interest: The Role of Long-Term Concession Agreements for Providing Transportation Infrastructure." *Transportation Research Record: Journal of the Transporation Research Board*, Vol. 2079/2008, 2009, pp. 88–95.

[48] Knack, R. "Transportation in Transition." *Planning,* Vol. 75, No. 5, May 2009, pp. 34–37.

customers' expectations for interacting with one another, availability of goods and services, economic opportunities, etc., then the expectations of transportation may be less.

Globalization

In simple terms, globalization refers to the increasing geographic scale of economic, social, and political interactions.[49] This includes not only the import and export of goods and monies but the growth in knowledge of different areas of the world. The increased connectivity of all people allows for information to be easily shared and thus opinions formed. Even in what may be considered tyrannical countries, we have seen the use of social media as a way of providing the world with information about what is happening. This raises the consciousness of the public about the world around them. Increased awareness of the world around them will shape the collective public's expectations. Public opinion about free trade, globalization, and international relations may affect expectations. With the increased globalization of society and the sometimes overwhelming availability of information, the public may alter their expectations based on this experience.

For example, the current trade deficit with China may influence the public's desire to purchase products made in China. Likewise, the political ramifications of producing coffee beans in certain countries may affect one's willingness to purchase coffee produced in those countries. Greater customer awareness of where products are produced may influence freight transportation. Moreover, having been accustomed to easily available and ubiquitous information for their entire lives, younger people may have a greater expectation of traveler information and communication. As this information becomes more easily available, the expectation that it be provided will also grow.

Movement toward Sustainability

The movement toward sustainability will have an impact on customer expectations based on the realities surrounding their current environments and situations. This movement is also tied to the public's attitudes about globalization. If the public makes a conscious effort to move toward a more sustainable society, this will include a sustainable economy, which may reduce the need for international freight movement. Or, other technological advances will enable these economies to operate without the current externalities such as environmental degradation. Over the last century, transportation, in all its forms, has resulted in the mass consumption of resources and goods beyond subsistence levels. To the extent that transportation and consumerism are linked and have causal effects on each other, transportation will be impacted by changing attitudes and practices regarding consumerism.[49] These changing attitudes will certainly impact expectations.

[49] ~~Janelle, D. A. "Globalizaton and~~ Research Issues in Transportation." *Journal of Transport Geography*, Vol. 5, No. 3, 1997, pp. 199–266.

Involvement in Decision Making

With regard to transportation project planning and implementation, greater communication and infrastructure technologies can foreseeably increase public participation. The public may expect new opportunities for involvement and an increased role in planning. Moreover, as the public becomes a more active participant in the decision making, the body of knowledge regarding transportation planning, programming, and funding will increase. This greater awareness can also impact transportation investments. As noted earlier, the implementing agency may affect customer expectations.

Privacy

Since the events of September 11, 2001, and the continued threats of terrorism, the public's attitude about privacy is likely to change over the next 50 years. The younger generation is typically unconcerned that their smartphones and debit card purchases reduce their privacy. They often view this as a cost of convenience. Waning concern over privacy will affect the type and rate of new technology implementation whether in-vehicle or roadside. Additionally, as more user fee approaches are demonstrated, the public may become more convinced that providers are able to protect their privacy.

Overall Transportation Opportunities

Transportation opportunities refer to the availability and accessibility of the public to be mobile. Customer expectation will largely be driven by factors that the public may not have direct control over. Circumstances of the world and society around them will affect and influence customer expectations. How quickly other changes in society occur and/or are adopted will also impact expectations. The availability of transportation options in terms of route type, mode choice, etc. will determine expectations. Moreover, in some instances, the very existence of transportation options may satisfy expectations. On the other hand, advances in other areas, such as technological advances, may negate the need for transportation opportunities, thereby lowering customer expectations.

World Descriptions

The drivers in the customer needs and expectations technical area are present to varying degrees in each world (figure C-11).

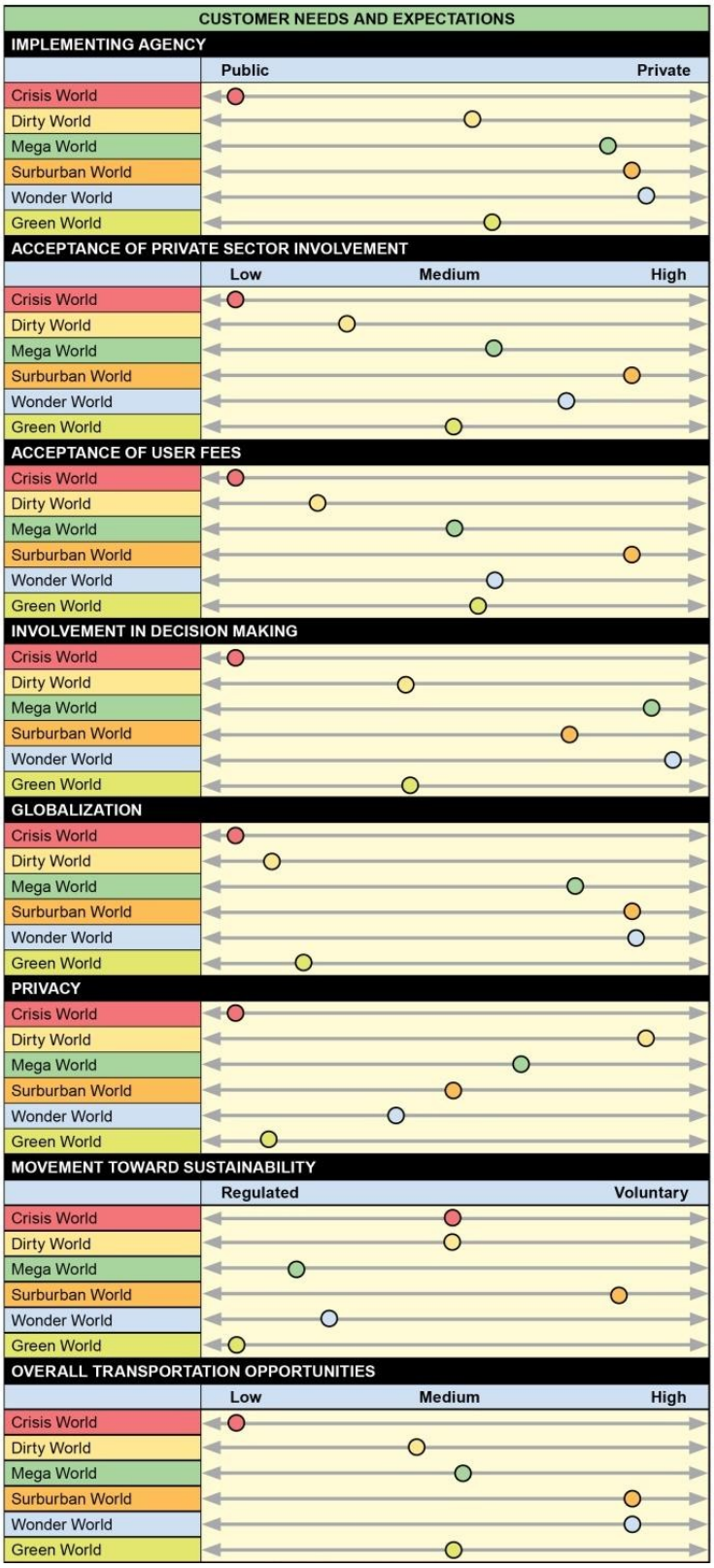

Figure C-11. Drivers for Customer Needs and Expectations Technical Area.

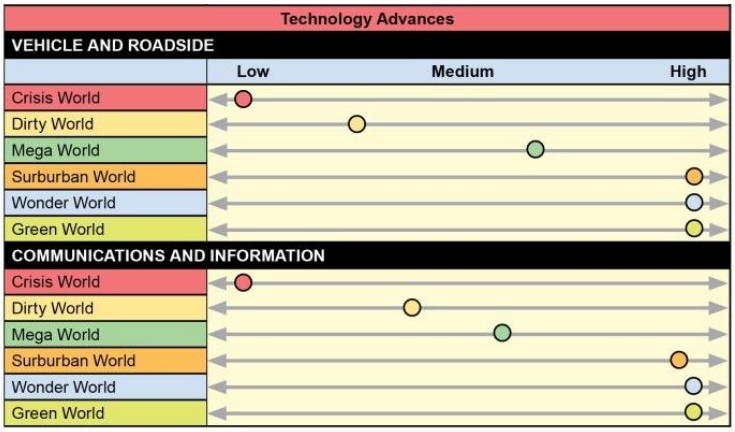

Figure C-11. Drivers for Customer Needs and Expectations Technical Area (Continued).

Crisis World

The following conditions concerning customer needs and expectations occur in Crisis World:

- In Crisis World, customer expectations are not addressed per se. People change the way they live to be more sustainable but not because they have made a conscious decision to do so but because they are responding to the circumstances Crisis World has created. The environment is compromised.
- There is very little economic growth, and dwindling natural resources lead to skyrocketing prices.
- It is likely that the public has very little expectation of the transportation system. Research has consistently shown that in times of dire economic distress, issues about transportation do not rank very high in the public's priorities.[50,51]
- It is likely that jobs, health care, and basic subsistence are the expectations of most people. However, if more people are forced to move to higher-density areas because coastal cities no longer exist due to increasing sea levels or other environmental catastrophes, there could be an expectation that governments (at all levels) provide some basic services. But, governments will be overwhelmed dealing with natural disaster crises. Moreover, there may be less of a need for transportation because only the very rich can afford long-distance travel, and private automobiles are a thing of the past. Travel demand, and thus expectation, decreases due to the economic conditions.

Dirty World

The following conditions concerning customer needs and expectations occur in Dirty World:

- Dirty World is very similar to Crisis World in that expectations are not addressed directly. What we can infer is that since there is no immediate danger from climate crises, the public has some level of expectation. However, due to depopulation in rural areas and

[50] Pew Research Center. *Economy Dominates Public's Agenda, Dims Hopes for the Future.* Pew Research Center, January 2011. http://people-press.org/2011/01/20/economy-dominates-publics-agenda-dims-hopes-for-the-future/. Accessed June 22, 2011.

[51] AAA. *Transportation Omnibus "Pockets of Pain" Survey.* 2006.

population shifts to denser areas, the government has had to prioritize crucial assets. This results in a disparity between rural and urban investments. The private sector will begin taking over more of the transportation system. Research indicates that this is a concern for the public. They have an expectation that governments will protect their best interest.

- The private sector takes over the best (i.e., most profitable) assets, while the public sector must decide whether to maintain or decommission other assets. Because there is not a pending crisis, change comes more slowly, and strategies to address sustainability such as pricing or increased government regulation have a more difficult time gaining acceptability.
- Because of the rising prices of resources, fewer people will have access to private automobiles, perhaps decreasing the demand for roadway infrastructure. Alternative-fuel vehicles are only available to small segments of society and thus are still only a small market share. In the latter half of the time period, public opinion may shift when the climate change issues become more urgent.
- The public will have higher expectations of projects implemented by the private sector, but at the same time the public may not be completely convinced that the privatization of transportation assets is in the public interest. This is especially true because of the disparities that may be created. The public may understand the need for involvement of the private sector yet may still have an expectation that the government provides transportation options.
- The public's expectation for involvement in decision making is most likely based on individual preferences. A person can be as involved as he or she wants to be, but there are no advanced technologies to enhance involvement.
- In Dirty World the public does not have a heightened sense of the effects of globalization; thus there is little expectation that either be curbed or encouraged. Changes are much slower, and the movement toward sustainability is encouraged more than regulated. Due to the weakened and still fragile economy, government is reluctant to impose strict restrictions or mandates that might inhibit economic recovery.

Mega World

The following conditions concerning customer needs and expectations occur in Mega World:

- In Mega World expectations of customer service are high. The world is increasing in productivity and enjoying a higher standard of living. Expectations are that this permeates through all levels of service including transportation. Concentrations of population in mega-regions may make transportation planning easier.
- Technology serves travelers of every mode, in transit, in vehicle, in infrastructure. Those living outside the mega-regions have an expectation that technology addresses their needs for communication in their travel options. The rising cost of carbon-based fuel puts increasing public pressure on agencies to provide a variety of travel options.
- The world describes 80 percent of the population living within the 10 mega-regions of the country; but there is no discussion of how other systems, water, wastewater, electrical, etc. will accommodate this growth or when. The public's tolerance for congestion, high taxes, delayed service, etc. depends on their expectation. There is an increase in privatization, but seemingly stronger controls may address public concerns. Areas outside

of the mega-regions generally decline due to funding concentration within the mega-regions. This is seen as an equity issue that the public does not find acceptable.

- The public becomes more accepting of privatization and user fees but, at the same time, has increased expectations of the private sector. Controls offered by governments could increase acceptance of private-sector involvement. Advanced technologies enable more transportation options and greater participation in the planning of those options. The public may become more aware of the effects of globalization and how transportation could be impacted. However, there is still a need for global commerce. These needs may be met through advanced technologies and regulations regarding sustainability.

Suburban World

The following conditions concerning customer needs and expectations occur in Suburban World:

- The difference between Suburban World and Mega World is that there is not a concentration of population in mega-regions. The population continues to disperse.
- Technology is the predominant factor that allows people to live and work where they choose. This may make transportation planning more difficult. The public may expect that all categories of roadways be maintained to a certain standard. The public agencies may not be able to provide this level of service. The public may then become more accepting of privatization in order to achieve a higher level of service. The move toward more decentralized governments may increase this acceptance because the public may feel they have more control of local issues that directly affect them.
- Market forces will drive much of the decision making, and this assumes a public acceptance. Devolution of decision making to local agencies may create disparities and inequities between communities. There may be a sense of every man for himself, which the public may not be accepting of.
- The advancement of technology has increased sustainability in this world, and it is easy to achieve without substantial regulation. There is considerable involvement in decision making since most of it occurs at the local level. Globalization is enhanced through technology, and there are high public expectations of it.

Wonder World

The following conditions concerning customer needs and expectations occur in Wonder World:

- In Wonder World much of everyday life from homes, to cars, to communication is automated. There has been such rapid advancement in technology that the expectations may have increased exponentially. People are free to live and work wherever they choose.
- The world assumes that privatization plays a large role in providing transportation solutions either through technology or asset management. However, because the country is so prosperous, the public may have an expectation that this remain under the government's control since there is enough available funding to support it. This assumes that public agencies are able to deliver the same high level of service people are receiving in other areas of their lives. It is likely that expectations will be high and require more agility on the part of providers to produce a high level of service.

Green World

The following conditions concerning customer needs and expectations occur in Green World:

- While Green World may sound utopian, it is highly regulated. For the public to be accepting of high levels of regulation, there must be a commensurate level of service. This world supposes that there is overall agreement on creating a more sustainable and green society. There is considerable investment in green technologies and infrastructure and a sustainable environment. Presumably there is substantial investment in these endeavors as well. The public may feel disenfranchised if these are strict top-down regulations rather than organic resolutions stemming from local priorities and interests.
- Society becomes more isolated because inter-city, inter-state travel is mostly non-existent. As with Mega World, most people live within cities, so there is an expectation that the transportation system will meet the needs to live within this environment. Because technology has evolved so rapidly, there may not be a need for infrastructure or the infrastructure may be very different in this world.
- There will most likely be a combination of projects from the private sector and public agencies. There is involvement in decision making, but it is mostly a top-down approach. There is very little globalization as the movement to sustainability has concentrated all aspects of life. The public has very low expectations of privacy in this regulated society.
- Overall transportation opportunities are varied. Very little long-distance travel occurs, and what does occur is very severely restricted by the government. Personal travel outside urban cores is very rare.

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TRAFFIC TECHNICAL AREA

Overview

Traffic Loading

Future vehicular demand on the highway system can be influenced by societal, demographic, economic, resource, and regulatory factors, all of which are addressed in companion white papers. For the purpose of this paper, traffic loading on the highway system will be examined from perspectives of capacity, mode, and flow characteristics.

Loading can be described as traffic demand in relation to capacity. Both demand and capacity are specific to individual highways, although there are common attributes within categories of urban highways, suburban highways, and rural highways. For example, urban highways in dense urban areas commonly have greater demand than available capacity allows, while rural highways that serve a connectivity function typically have less demand than the available capacity would allow. The ability to build additional highway capacity can be influenced by regulatory and societal factors. Examples include the availability of funding, economic, policy directives that limit

highway development, or unacceptable impacts of highway expansion on the built or natural environments.

There is a temporal aspect to traffic loading of highways in metropolitan regions that are experiencing high levels of congestion during peak hours and minimal congestion during off-peak periods. Sizing the infrastructure for peak conditions is inefficient and infeasible, but actions to significantly ration and redistribute demand through trip reduction or pricing have met with resistance.

Traffic Flow Characteristics—Flow, Speed, and Density

In addition to background demand, the way that the highway infrastructure carries that demand can influence capacity requirements. Traffic flow describes the movement of individual vehicles and their interactions with the highway and with each other. The three main characteristics of traffic movement are:

- Flow—rate of movement, such as vehicles per time period, measured over a variety of periods depending on the situation (15 minute, hourly, or daily).
- Density—concentration of vehicles, such as the number of vehicles over a length of roadway and measured by occupancy.
- Speed—generally measured as velocity (time mean speed) but also measured point to point (across a length of highway).

A related parameter is vehicle headway, which can be defined as either the time between vehicles or the distance between vehicles.

Why is traffic flow important? As vehicle design and associated in-vehicle and roadside technology develop over time, the ability to influence flow, density, speed, and headway without increasing the footprint of the existing infrastructure, or by minimizing its expansion, can result in greater loading of the system than currently allowed under existing standards.

Liability issues can be a major restriction to innovation in reducing headways. Demonstrations of automated highway systems have shown that headways can be reduced, but unresolved is the issue of who is liable when something goes wrong. This is one of the limitations to moving technology-oriented innovations into practice.

Drivers of Traffic

The drivers behind handling traffic fall into these categories:

- Demand to capacity.
- Modal alternatives to passenger vehicles—person movement.
- Modal alternatives to commercial vehicles—goods movement.
- Vehicle type and characteristics.
- Vehicle technology.

Demand to Capacity

In examining the future scenarios, there are three possible traffic loading perspectives for the highway system:

- Demand is increasing relative to capacity (i.e., growth in demand significantly outpaces increase in capacity).
- Demand is stable relative to capacity (i.e., growth in demand is coupled with a commensurate increase in capacity).
- Demand is managed through technology and pricing, particularly with respect to equalizing demand with capacity during the most congested periods.

Modal Alternatives to Passenger Vehicles—Person Movement

The preponderance of alternative modes for carrying people influences the level of traffic demand on the highway system. Will there be more cars or fewer cars on the highway system as a result of alternative mode development? Fundamentally, demand for bus and rail transit and other non-motorized modes may respond to two factors:

- The investment in infrastructure to make transit and alternative passenger modes more accessible or more attractive.
- Demand (or shift of mode) to transit because of individual lack of alternatives due to economics, geography, trip characteristics, etc.

These two overarching factors are represented in various forms, which are highlighted in Table C-1.

Table 1. Factors Affecting the Use of Alternative Passenger Modes.

Increase in Alternative Mode Opportunities	Decrease in Alternative Mode Opportunities
High residential density	Low-density suburban residential development
High employment density, locational decisions by businesses/industries in relation to transit opportunities	Dispersed suburban and rural employment
Consistent work schedule and job location	Wide variations in work schedules and job locations
Short trips	Long trips
High number of direct trips	High number of linked or chained trips; complicated travel patterns for working parents, particularly single parents
Low number of cars per household	High number of cars per household
Increase in transit funding	Decrease in transit funding
Increase in personal economic hardship (loss of income, high gas prices, etc.)	Increase in personal economic wealth (growth in income, low gas prices, etc.)
Unattractiveness of driving	Cleaner vehicles, vehicle attractiveness

Modal Alternatives to Commercial Vehicles—Goods Movement

Transporting freight efficiently and cost-effectively is vital to U.S. economic strength. Most freight is currently moved by truck, as much as five times the amount moved by rail. Railroads are economically viable for long distances of 500–750 miles. Trucking on the highway system is most efficient for distances less than 500 miles. Changes in the method of moving freight can influence highway demand. The question is: will there be more trucks or fewer trucks on the highway system in the future scenarios?

Truck volumes are approaching very high levels on the interstate highway system and are projected to continue to increase:

- The average interstate highway mile carries 10,500 trucks, and that will rise to 22,700 by 2035.
- By 2035, more than a third of America's interstate highways will carry more than 25,000 trucks per day.[52]

The factors that can influence freight flow include the following:

- New or alternative delivery systems—a shift to rail or development of new delivery systems, such as the freight shuttle.
- Regulatory environment—a highly regulated environment would result in lower demand, while a deregulated environment would lead to higher demand, and likely cheaper prices with a wider geographic coverage.
- Consumer shopping—in 1992, 15 percent of retail sales occurred through nonstore retailing; in 2010, 55 percent of sales occurred through nonstore. If this trend continues, it will drive freight supply and demand away from long-haul carriers and toward air carriers coupled with less-than-truck load or smaller-class truck freight shipments.[53]
- Urban form—denser development may affect decisions about urban freight facilities, which tend to be located on the expanding urban/rural fringe. Urban form may also influence time-of-day deliveries and intermodal connections.
- Congestion reduction measures—any policy or program that reduces congestion across the system could have a positive effect on goods movement and a concomitant benefit to business productivity.
- Pricing may lead to greater understanding and appreciation of the direct economic impacts of efficient goods movement to national and regional economies (job creation and regional competitiveness).
- Globalization—increases in foreign trade will lead to growth into maritime and inland port traffic, and the expansion in containership traffic will exacerbate the need for landside connectivity of ports to points of transfer and delivery.

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[52] AASHTO. "America's Freight Transportation Network; Struggling to Keep Up." May 2007. http://www.transportation1.org/tif3report/freight.html.

[53] TRB. Urban Freight Movement. http://onlinepubs.trb.org/onlinepubs/millennium/00139.pdf.

Vehicle Type and Characteristics

Traffic flow is more consistent and uniform when variations in vehicle type and vehicle characteristics are minimized. For example, commercial vehicle types may vary in size and weight, from longer combination vehicles (LCVs) in rural and long-distance applications to smaller-class vehicles in urban settings. These vehicles have different acceleration and braking characteristics, which influence highway traffic flow within a mix of vehicle types. The differences in acceleration characteristics could be mitigated by separating the traffic stream through creation of truck-only lanes or facilities, or conversely passenger-car-only lanes.

Vehicle Technology

Leading edge vehicle technologies—advanced wireless communications, onboard computer processing, advanced vehicle sensors, GPS navigation, smart infrastructure, and others—have the potential to identify threats and hazards on the roadway and communicate this information over wireless networks to give drivers alerts and warnings. In addition to the safety benefits, vehicle connectivity can potentially reduce vehicle headway, which influences the demand-carrying capacity of a highway.

This connectivity offers the opportunity to know much more about traffic and roadway conditions, supporting quicker incident detection and clearance. It may be possible for equipped vehicles to anonymously send information that includes travel time and environmental conditions, making it possible one day to know traffic conditions and support load equalization across the system and dynamic rerouting. Technological improvements in vehicle equipment related to acceleration and braking that are designed for safety can potentially smooth flow by creating a more operationally homogenous vehicle mix.

World Descriptions

The drivers in the traffic technical area are present to varying degrees in each world (figure C-12).

Crisis World

The following conditions concerning traffic occur in Crisis World:

- Crisis World is characterized by persistent and long-term crises that range from environmental to economic to social. In Crisis World, the United States lacks the means to adequately respond to challenges, leading to significant changes in the daily status quo for the population.
- Demand in relation to capacity for the highway system is largely stable, meaning that in the crisis situation demand is lower and stable and capacity is also unchanged.
- As greater focus is placed on urban mega-regions, transit alternatives emerge as people take short trips and have limited resources for vehicular travel, but there are also limited resources to devote to transportation infrastructure to support mass transit.
- Freight alternatives are limited, and the vehicle fleet has wide variations in operating characteristics with little in the way of technological advancement.

Dirty World

The following conditions concerning traffic occur in Dirty World:

- Dirty World is similar to Crisis World, with the exception that crises related to climate change are less pronounced.
- Demand in relation to capacity for the highway system is increasing, meaning that demand is greater than in Crisis World, but capacity is unchanged due to limited financial resources.
- As greater focus is placed on urban mega-regions, transit alternatives emerge as people take short trips and have limited resources for vehicular travel, but there are limited resources to devote to transportation infrastructure.
- Freight demand alternatives are limited, and the vehicle fleet has wide variations with little in the way of technological advancement.

Figure C-12. Drivers for Traffic Technical Area.

Mega World

The following conditions concerning traffic occur in Mega World:

- Mega World is presented as the status quo, where current trends in terms of economy and population growth are continued. The general population becomes concentrated into 10 major mega-regions.
- Highway demand outstrips capacity in Mega World, but with the emergence of private-sector involvement in capacity development, there is more stability.
- Transit alternatives emerge as a strong component of the system since the concentrated mega-regions focus provides opportunities for viable transit service.
- Vehicle technologies emerge to support demand management of the system.

Suburban World

The following conditions concerning traffic occur in Suburban World:

- Suburban World is very similar to Mega World, with the notable exception that the population is diffused throughout the country in smaller secondary and tertiary cities.
- As technology drives a more dispersed development pattern, demand to capacity becomes more stable as traffic loading is likewise dispersed.
- Transit alternatives have lower opportunity for success because of residential and employment locations.
- Freight alternatives emerge as consumers place a greater reliance on nonstore shopping to purchase goods. This results in a more homogenous vehicle characteristic mix.

Wonder World

The following conditions concerning traffic occur in Wonder World:

- Wonder World is characterized by faster than anticipated economic and technological development. As a result, there is a generalized decentralization of the economy.
- Technological developments and user acceptance of those developments result in better management of the system through pricing applications and vehicle technology innovations.
- Technology advancements also lead to innovative freight movement solutions and a more homogenous fleet of vehicles in terms of acceleration and braking characteristics, thus allowing more demand to be served with a lower amount of capacity.

Green World

The following conditions concerning traffic occur in Green World:

- This world is resembles Wonder World. The primary difference, however, is that in Green World there is broad consensus about the importance of sustainability and the need for a green society.

- This new outlook permeates most public policy decisions. The results mirror Wonder World in many respects, but with the greater emphasis on sustainability there is more support for congestion pricing, transit services, freight alternatives that minimize environmental impact (such as the freight shuttle), and more reliance on technology to help drivers make sustainable travel choices.

SAFETY TECHNICAL AREA

Overview

Transportation safety involves safety ratings, degradation, risk assessment, and structural integrity. The risks that affect safety are natural disasters, weather, frequency of use, degradation, and accidents. The current greatest causes for roadway accidents are given by the International Road Assessment Program (IRAP, 2010). Highway transportation safety includes not only protecting the drivers/operators/passengers but also construction workers in the work-zone areas.

Poor road surface conditions affect drivers because they can lose control of their vehicles, causing injuries to themselves or damages to other vehicles. Proper and carefully planned road designs and traffic management (including adequate information to road users) can reduce congestions and prevent accidents. An example of innovative design is the "Safety Edge," which is targeted at reducing severe roadway departure crashes and improving pavement durability. Recent studies have shown that crashes involving pavement edge drop-offs greater than 2.5 inches are more severe and two to four times as likely to be fatal than other roadway departure crashes (U.S. Department of Transportation).

The difficulty of managing safety in highway transportation is dealing with the continuous flow of high-speed vehicles in relatively tightly managed space. This is due to the fact that most preventive-maintenance, regular repairs in the past have typically allowed for traffic to pass through the work zones, causing disruption to the flow of traffic and also to the workers. Additionally, any disruption to the flow can have a cascading effect on the entire flow of traffic. Unfortunately, too many factors (i.e., operator decision, driver skill, vehicle condition, road design, road condition, and weather) individually or in combination can lead to deadly accidents.

Drivers of Safety

The drivers behind improving safety fall into these categories:

- Current level of serviceability.
- Domestic spending.
- Public demand.
- Development of technology (double-edged sword).
- Public willingness to be responsible drivers.
- Government regulation on safety management.

Current Level of Serviceability

Studies have shown that adequate auditing and frequent monitoring lead to fewer accidents. For example, a Road Safety Audit (RSA) is a very effective tool to reduce injuries and fatalities on

our nation's roadways. It quantifiably estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users. Timely repair and maintenance following the audit will reduce accidents on the road.

Domestic Spending

Lack of funding can also seriously affect the safety of workers in the field. With the demand for reduced costs, safety may be jeopardized in this process. Training of personnel, establishing current technical standards, and improving management routines must be properly funded and kept current in order to establish an adequate work environment (Kristiansen, 2005).

Public Demand

Public demand will have a large effect on how the government responds to monitoring the current serviceability of the highway infrastructure. As more people push for a safer driving environment, the government will also respond faster and more efficiently to meet those demands. Currently, construction work on existing highway infrastructure is difficult with partial lane closures and moving traffic, which leads to accidents. As people become more educated and concerned with safety issues, the government may find that people are more accepting of innovative approaches to maintain the current infrastructures even at some inconvenience to them.

For example, with advance notice, organized public outreach, and communication with the public, it may be possible to completely close the lanes and eliminate traffic, reducing the risk of accidents. Even if a complete closure is not possible, additional interventions can discourage speeding or accidents near the construction area.

Development of Technology (Double-Edged Sword)

Construction work is not the only source of disruption to the current flow of traffic. Today, increase use of cell phones and driving while texting or emailing are very serious threats to highway safety. So while, technological improvements bring new and innovative ways to reduce accidents, they also play a large role in changing our driving habits.

Some positive use of technology to improve safety includes sophisticated ITS, nondestructive methods or equipment to conduct condition assessments. For example, advanced road condition detection equipment such as Versatile Onboard Traffic Embedded Roaming Sensors (VOTERS) is being developed by Northeastern University. This tool will enable safer alternative ways to examine the current condition of roadways with acoustic sensors and radars to detect "delamination, trapped moisture, rebar corrosion or other road imperfections that are unnoticeable to the surface" (NIST, 2009).

Public Willingness to Be Responsible Drivers

With the growing number of aging population and young drivers, traffic safety becomes even more challenging. Elder drivers pose a threat to themselves because they cannot respond as quickly to emergency situations, with declining response time and physical conditions. Young drivers on the other hand can be reckless, easily distracted, and aggressive on the road. Better

strategies are needed to protect these populations from hurting themselves and other drivers. One of these strategies can be educating them to become more responsible and aware of safe and defensive driving skills, which will ultimately change their driving attitude and behavior on the road. The goal of the education would be to make the public more proactive on being safe and responsible drivers on the road.

Government Regulation on Safety Management

Government regulation and enforcement and public demand go hand in hand. As people demand better service and protection from the government, the government will seek to enforce stronger laws and tight regulations to protect the people. The government may enforce stringent preplanning and traffic safety management plans from contractors or even enforce real-time monitoring of traffic with sophisticated technology to track every vehicle and passenger on the road.

World Descriptions

The drivers in the safety technical area are present to varying degrees in each world (figure C-13).

Crisis World

The following conditions concerning technology and innovations occur in Crisis World:

- In Crisis World, there are no opportunities to construct or implement any kind of rehabilitation of the roadways. The United States struggles to maintain the current infrastructure and is forced to shut down services in some areas. Painful but necessary downsizing happens to the current infrastructure network. Agencies are forced to maintain the rest of the existing infrastructure in service with minimum budget.
- With no budget, there is no development in technology and adoption that takes place. This naturally leaves less money to be spent on monitoring and adding fancy and costly safety equipment such as ITS and steel barriers. However, this does not automatically lead to more traffic-related deaths or accidents near the work-zone areas. In the Crisis World, people in general have a much lower expectations of government to add sophisticated safety measures. The public takes it upon themselves to be more cautious and practice safe driving.
- There is a big movement among people to work together to rebuild America. The richest people in the United States start to focus their resources and efforts on resolving issues that exist here at home. The people in general become more sustainable in their way of life, which slowly starts to improve the quality of life. The government on the other hand is seeking frantically to find ways to recover from the recession and is not able to fully enforce or regulate any restrictions yet.

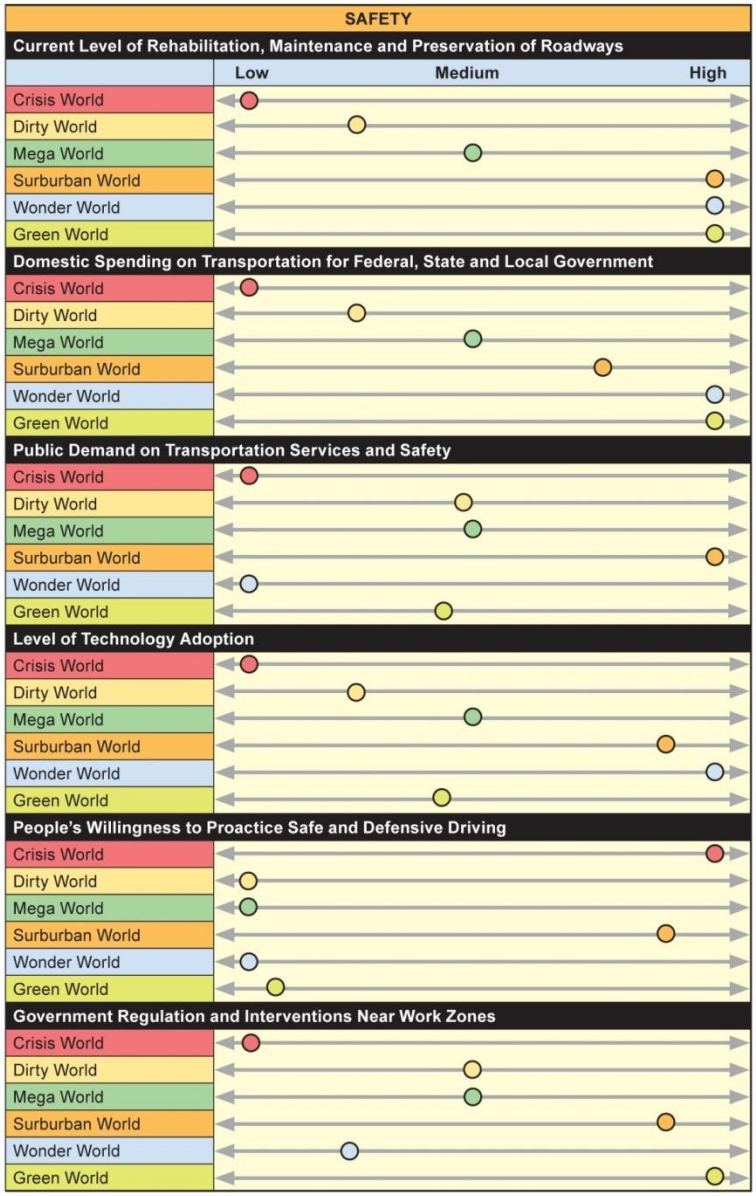

Figure C-13. Drivers for Safety Technical Area.

Dirty World

The following conditions concerning safety occur in Dirty World:

- In Dirty World, there is just barely enough funding to maintain the existing infrastructure in average condition. However, without some immediate or near-future interventions, the existing infrastructures will not last long. There is a great deal of pressure between politics to build better policies to improve the conditions of the critical infrastructures. This forces the government to actively engage in research. The nation is seeking professionals, academics, and experts in the field to determine the best methodology to proceed in the next decade. Research starts to pick up at a very fast pace as government starts to release more research grants.

- In Dirty World, there is no significant change in the number of older population yet. However, there is an increase in the number of young drivers on the road. This young generation is more technological savvy about using cell phones, texting, Twitter, Wi-Fi, iPods, iPhones, and GPS machines, which allows real-time networking and socializing. They are constantly responding and interacting with these and do not draw the boundary of when they need to stop to focus on another task. Hence, safety in traffic and work-zone areas becomes more problematic as young generations do not realize the danger of being distracted on the road. There is a large increase in the number of accidents caused by careless young drivers.
- With time, people see the rise in the number of traffic-related accidents and start to demand better safety measures from the government. Lawmakers are forced to implement stronger punishments and penalties on distracted and reckless drivers. Steel barrier systems, for instance, are migrating into the U.S. market and being used to provide positive protection in very-high-risk areas. ITS provides road operators and users with better travel time and warning information. Providing adequate visibility with lights is another measure that allows drivers to safely travel around the work zone at night. However, in Dirty World, justifying the cost to add safety measures is difficult, and obtaining adequate funding is still problematic. The government tries to relieve the situation by working with various parties. The government tries to collaborate with cell phone, wireless network providers, and miscellaneous handheld device manufacturers to improve traffic safety. The government also engages more with the public to educate communities and young drivers about practicing safe driving skills.

Mega World

The following conditions concerning safety occur in Mega World:

- In Mega World, the economy starts to improve drastically from Dirty World. The government is proactive about maintaining and rehabilitating the roadways. People expect better and reliable service from the government in terms of providing adequate transportation means and traffic safety. People are more educated and more responsive to traffic laws, etiquettes, and safe driving. People also become more conscience about their health and well-being. Health care starts to improve, and there is a growing number of aging population and young population.
- As people start to concentrate more and more in 10 mega-regions, there is a greater need to reduce congestion, reduce pollution, and improve the environment. With adequate funding, the United States searches for alternative transportation modes, alternative energy, intelligent cars, and technologies to alleviate congestion and promote remote working.
- In Mega World, the United States tries to implement some of these new technologies. Unfortunately, some of these transportation technologies are still in their infancy. Some time and money are lost pursuing some technologies that do not materialize or are proven to be useless in the real world.
- Ensuring the safety of drivers and workers in construction work zones becomes very challenging as drivers become impatient and aggressive drivers enter congested areas. The United States also has to build new strategies to incorporate the large number of

elderly drivers and young drivers. As business is booming, everyone is working around the clock. After a slow economy, people and companies are enjoying the vast amount of work and continue to text and conduct business as they sit and wait in traffic in central business districts. With the economy improving, young and elderly drivers are also enjoying and spending more leisure time outside and traveling, which also adds to the current traffic.

- With adequate funding, the United States tries to implement as many other safety measures and technologies to reduce the growing number of accidents. The United States tries hard to encourage and fund research in the area of transportation safety and technologies that would accommodate people's need to work and spend time more efficiently. For example, the government might be interested in driverless vehicles and faster, reliable semi-public cars, which are smaller and provide more privacy than a regular bus or a commuter train. For workers near construction zones, the government may close down the entire section during construction, implement sophisticated/accurate real-time GPS and ITS equipment to alert drivers in advance, and reroute traffic.

Suburban World

The following conditions concerning safety occur in Suburban World:

- Suburban World is similar to Mega World. There is a large increase in the number of young and elderly population and people demand better service from the government in regard to safety and well-being. However, in Suburban World, technology advances and allows people to live in the suburb and conduct business anywhere from a remote location. Commuter trains, semi-public cars, and buses traveling into the cities may become obsolete as demand starts to decline. Both the younger and elderly populations start to meet near where they reside, and there is no need to travel far by personal vehicles to get to popular meeting places, which results in less traffic and fewer accidents involving personal vehicles on highways.
- However, this does not directly relate to less traffic near highways, rails, or ports. Most of the highways are dominated by freight transportation as people's demand for finished goods starts to rise. The United States focuses more on improving the quality of pavement materials to support and endure heavy loads, develop vehicle technologies that alert truck drivers on lane departure, address capacity and transition between ports and boarders, mitigate environmental impacts, and secure the transportation of hazardous materials. Hence, ensuring the safety of drivers and workers near other intermodal freight transportation becomes critical.
- The United States maintains, prevents deterioration, and rehabilitates all of these transportation network systems well in advance with enough funding. However, the United States still struggles to improve safety near construction work zones since most of the vehicles are large trucks now. The United States considers dividing and designating truck lanes or highways from small vehicles to reduce the number of accidents and also considers closing down an entire section of the highway during construction and rehabilitation to improve the safety of workers and drivers.
- In Suburban World, people may travel more by air as they try to get to more remote, exotic places to visit. Traffic safety near work zones may now include construction of many smaller airports as well and protecting the workers from many flights that depart or

arrive at these airports. New risks and safety measures may need to be considered to protect the people and workers. The government is in the transition of re-evaluating most of its current safety measures near highways, railways, airports, and seaports to accommodate the transition in public transportation modes and primary users. People are more cautious driving near and around new transportation modes and near construction sites.

Wonder World

The following conditions concerning safety occur in Wonder World:

- In Wonder World, technology is so advanced and tested in the field that there is no human interaction needed during the construction or rehabilitation of roadways, railways, and near ports. The United States also has enough funding to implement any kind of maintenance and preservation methods well in advance. Intelligent equipment and robots replace workers in the field.
- Vehicles carrying people are also able to detect objects well in advance to maneuver around any kind of obstacle, and emergency backup systems prevent any unforeseen accidents from happening. This is a great relief to the large number of younger and elderly populations since they do not have to rely on their ability to drive. All the data networks are synchronized to talk to each other. There are no unintended side effects from the data synchronization, and computers/robots do not take over the human species as many people are worry.
- The United States is able to achieve zero accidents near construction in transportation. With no accidents, there is no demand from the public to increase safety measures and no need for people to practice safe and defensive driving. Government loosely regulates to promote the private sector being more innovative and creative.
- However, a growing number of Americans worry as some private companies start to look into technologies that can combine human brain power into operating machines. The intensions may be worthy since this may allow human interventions when dangerous situations arise and will allow physically impaired people to exercise their brain power, but some worry that this will allow computers to take over the human species as we become incapable of controlling the monster that we created.

Green World

The following conditions concerning safety occur in Green World:

- Green World is very similar to Wonder World. The United States has a diverse mix of populations and an immensely large number of young and elderly populations. In Green World, the government recognizes the concern many have about intelligent/self-thinking computers that may take control of what humans are now controlling. The government starts to police the kind of research that private organizations can conduct.
- The government also monitors and records everything people say and do to protect the public. The downside of being creative and developing innovative technologies is that some people might take advantage of this to commit a crime and threaten innocent people. The government intervenes to protect the safety and well-being of its people by

taking away one of the fundamental rights, which is individual privacy. However, people see this as a necessary step to protect the world from being dominated by computers.

- In Green World, people expect the government to provide orders and people to follow those orders. The government is able to easily shut down transportation services to maintain or rehabilitate current infrastructures. With robots that can operate with human thoughts, there are no human casualties near work zones. People are very cooperative and avoid dangerous situations such as being near a construction zone since all of their vehicles are computer programmed by the government to avoid areas that can be considered dangerous. With the government policing private companies, people do not have to worry about computers taking over the world and are able to live in complete peace.

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