Guide on the Consistent Application of Traffic Analysis Tools and Methods

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Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

FOREWORD

The Federal Highway Administration, in support of the Traffic Analysis and Simulation Pooled Fund Study, initiated this study to identify and address consistency in the selection and use of traffic analysis tools. This document offers recommendations on the management, planning, and conduct of traffic analysis that will promote greater traffic analysis tool consistency over the typical project development life cycle. The key to managing consistency of traffic analyses throughout the various stages of project development is a master plan, which is called the project delivery analysis plan (PDAP) for the purposes of this document. The PDAP is a scalable master scope that describes the project, its purpose, and the objectives of the traffic analysis. It identifies the measures of effectiveness that will be used to evaluate the project and its alternatives, describes the traffic analysis approach (including tools, assumptions, and parameters), identifies risks and contingency plans for dealing with those risks, determines the resource requirements, and lays out the time schedule for the analysis. This guidebook is directed toward professionals operating in State departments of transportation and other agencies responsible for transportation project development and delivery.

Joe Peters
Director, Office of Operations
Research and Development

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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EXECUTIVE SUMMARY

The Federal Highway Administration (FHWA), in support of the Traffic Analysis and Simulation Pooled Fund Study (PFS), initiated this study to identify and address consistency in the selection and use of traffic analysis tools. This document offers recommendations on the management, planning, and conduct of traffic analysis that will promote greater traffic analysis tool consistency over the typical project development life cycle. It is directed toward professionals operating in State departments of transportation and other agencies responsible for transportation project development and delivery.

The purpose of this guidebook is to provide technical advice on the selection and use of traffic analysis tools and methods in a manner that promotes consistency over the course of the project development life cycle. Terminology and processes contained in this guidebook are a composite of the experiences of and approaches used by transportation agencies across the country for instructive and consistency purposes. When using this guidance, individual agencies will need to consider how their own terminology, processes, and procedures correspond to those contained in this document.

ANALYSIS TOOLS AND THE PROJECT DEVELOPMENT LIFE CYCLE

A transportation improvement project typically goes through the following stages of development:

1. Project need identification.
2. Project initiation.
3. Project clearance
4. Plans, specifications, and estimates (PS&E).
5. Construction.
6. Operation.

In the early stages of project development, relatively little has been defined about the project. Consequently, the analysis has to be relatively broad and comprehensive, with the focus of the analysis increasing as the project and its alternatives are defined in the later stages.

The following categories of traffic analysis tools are available for evaluating a transportation improvement project:(1)

- Sketch-planning tools.
- Travel demand models.
- Analytical/deterministic tools (based on the *Highway Capacity Manual* (HCM)).
- Traffic signal optimization tools.
- Simulation models (macroscopic, mesoscopic, and microscopic).

Figure 1 shows the optimal application ranges for each of the traffic analysis tool types. A wide vertical band indicates that the project development stage falls within the range of application for which the tool is best suited. A thin vertical band indicates that the tool can be used for that stage of project development but is less well-suited for that application.

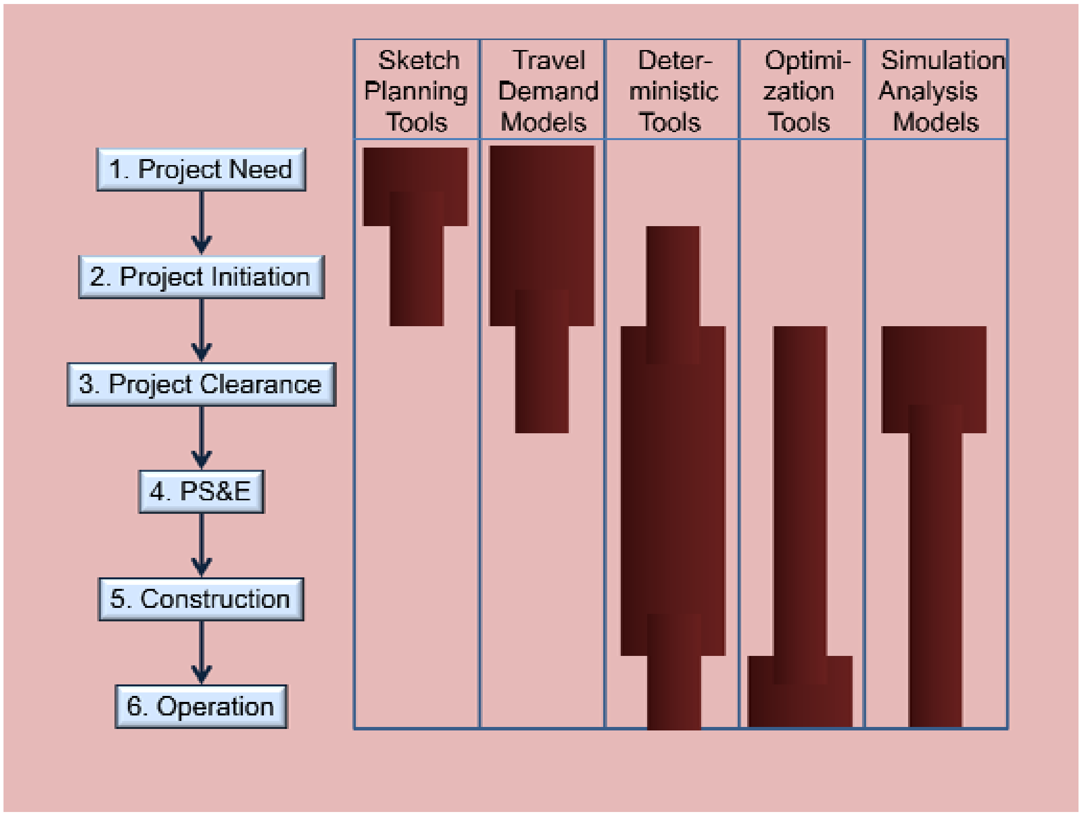


Figure 1. Chart. Traffic analysis tool application ranges in project development.

MANAGING CONSISTENCY THROUGHOUT PROJECT DEVELOPMENT

The key to managing consistency of the traffic analyses throughout the various stages of project development is having a master plan for the analysis that is scaled to the needs of each stage of the process. This plan is the project delivery analysis plan (PDAP) described in chapter 3.

The PDAP is a scalable master scope that describes the project, its purpose, and the objectives of the traffic analysis. It identifies the measures of effectiveness (MOEs) that will be used to evaluate the project and its alternatives. It also describes the traffic analysis approach (including tools, assumptions, and parameters) and identifies risks and contingency plans for dealing with those risks. It determines the resource requirements and lays out the time schedule for the analysis.

The remaining chapters give advice on the contents of the PDAP, as follows:

- Chapter 4: Selecting Consistent MOEs.
- Chapter 5: Selecting Consistent Tools, Parameters, and Assumptions.
- Chapter 6: Utilizing Outputs from Different Tools.
- Chapter 7: Visualization and Communication Aides.

CHAPTER 1. INTRODUCTION

The FHWA, in support of the Traffic Analysis and Simulation PFS, initiated this study to identify and address consistency in the selection and use of traffic analysis tools. This report offers recommendations on the management, planning, and conduct of traffic analysis that will promote greater traffic analysis tool consistency over the typical project development life cycle. It is directed toward professionals operating in State departments of transportation and other agencies responsible for transportation project development and delivery.

PURPOSE

The purpose of this guidebook is to provide technical advice on the selection and use of traffic analysis tools and other methods in a manner that promotes consistency over the course of the project development life cycle. This guidebook is designed to do the following:

- Offer advice on setting up consistent study assumptions and parameters and on selecting MOEs that are as directly comparable as possible.
- Offer advice on how to prepare each type of analysis in a manner that allows the MOEs of different tools to complement one another without confusing and contradictory results.
- Offer advice on the utilization, interpretation, and integration of the range of data and multiple measures produced by multiple traffic analysis tools employed over a project's development life cycle.
- Provide interim direction, drawing upon current and ongoing efforts, until such time as superior application guidance or functionality can be provided by the vendor community or through further research.
- Provide an approach to the development of a study scope in a manner that anticipates the analysis requirements throughout the life cycle of a study. Consideration should be given to the benefits and limitations of conducting larger geographic studies useful for more stages of project analysis versus the agglomeration of smaller, more focused traffic analysis studies into a larger, unified analysis. The guidance offers advice on how to develop studies in a consistent and scalable manner.

TARGET AUDIENCE

The primary audience for this guidance is the technical staff associated with participating State and other government agencies associated with the PFS on Traffic Analysis and Simulation, TPF-5(176).

APPROACH

Development of this guidebook included a preliminary literature review to assess the quality of the guidance currently available on the use of traffic analysis tools to achieve consistent analytical results. An expert panel was recruited to review interim results and provide guidance on the technical direction of the effort. A questionnaire was distributed and a series of interviews conducted that culminated in a report on the current state of the practice. Feedback to that report, additional interviews, and literature review were conducted to support identification of key consistency issues and to support the development of this document.

Terminology and processes contained in this guidebook are a composite of the experiences of and approaches used by transportation agencies across the country for instructive and consistency purposes. When using this guidance, individual agencies will need to consider how their own terminology, processes, and procedures correspond to those contained in this document.

PROBLEM STATEMENT

Initial interviews with State transportation staff revealed that, though reference documents are generally available for most analysis tools, it is often difficult to incorporate the documents' guidance into actual practice. This is often because of staff, budget, and resource limitations. However, a significant hindrance is that each available reference is focused on a specific analysis tool and not on how the tool fits into the complete project development life cycle.

Additional interviews with senior-level analysts and practitioners revealed that managers face many challenges in identifying and assembling the appropriate level of effort, staff, and support needed to employ the variety of traffic analysis tools required to meet traffic analysis goals.

For most State transportation agencies, issues with tool use inconsistency do not reflect a need for additional tool references. A central theme in the course of this study was that despite the existence of tool-specific references, the guidance and recommendations contained in those references have not always been adequately implemented for various reasons, including the disjoint nature of the guidance. Guidance is given on how to use the specific tool but not on how the use of the tool fits into an overall traffic analysis process.

This report attempts to bridge the gaps between available tool-specific references by providing an overall management approach to the employment of traffic analysis tools over the life cycle of project development. This report is not focused on telling analysts how to use specific traffic analysis tools because that information is already available from references such as the FHWA *Traffic Analysis Tools Program*.[(1)] Instead, this report recommends steps that technical analysts and project development managers can take to improve the consistency and effectiveness of their traffic analyses over the course of the project development life cycle.

CHAPTER 2. CHALLENGES TO CONSISTENT ANALYSIS AND RESULTS

This chapter describes the benefits of performing consistent analyses over the course of the project development life cycle and identifies the many challenges to achieving and maintaining consistent results throughout the various stages of project development.

First, the major stages of a typical project development life cycle are described. Current project development traffic analysis practice is described, followed by a brief summary of the major types of traffic analysis tools used in project development. The purpose of these early sections is to establish terminology. It is not the intent of this chapter to identify a specific project development process that all agencies must follow nor to identify the traffic analysis tools that all agencies must use.

The remaining sections of this chapter describe the benefits of maintaining a consistent analysis process over the course of project development and highlight the major challenges to achieving this objective.

THE PROJECT DEVELOPMENT LIFE CYCLE

A transportation improvement project goes through an extensive project development life cycle, starting with identification of a project need and ending with the construction of the project. During this time, the project traffic analysis may pass through many hands and many subdivisions of the organization. The major milestones of project development are: identification of project need, project initiation, project clearance, project PS&E, and, finally, project construction (see figure 2). For an example of the project development life cycle for a State transportation agency, see the California Department of Transportation's *Project Development Procedures Manual*.[(2)]

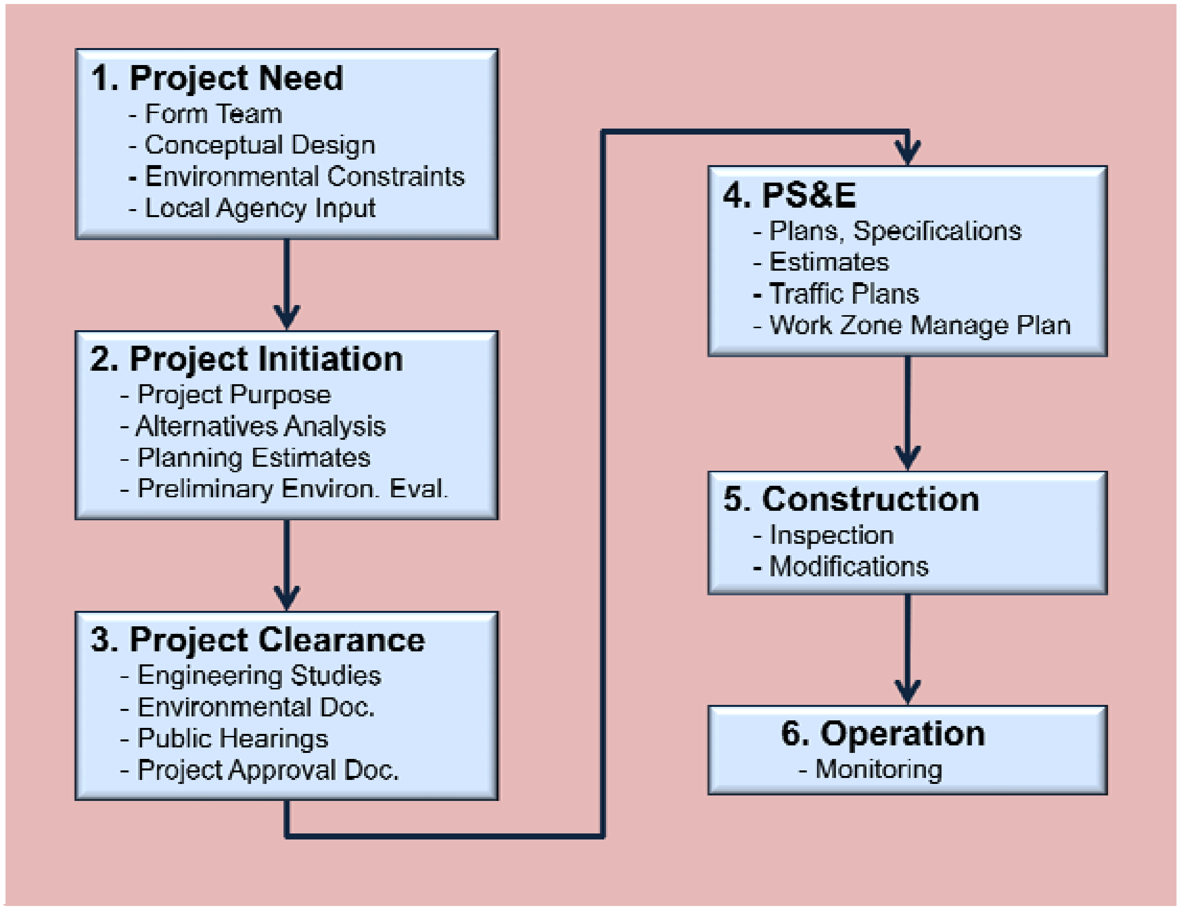


Figure 2. Chart. The project development life cycle.

Project Need

The identification of project need is usually the result of one or more studies or plans. For cases where the project need statement is vague, a good analysis plan can help focus the need statement. At this stage of the project development process, the agency reviews the planning studies, reports, and plans that identified the need for the project. The agency identifies potential environmental constraints and defines the problem being addressed by the project. The agency establishes a project development team, prepares a traffic concept report, develops concept geometrics for the project, and obtains public and local agency input. At this point, the project need is well-defined, but the project itself is not yet defined in any great detail.

Project Initiation

At this stage, the agency prepares a formal project initiation document depending on the specific policies and procedures of the agency. This document usually defines the need and project purpose, develops concept alternatives, presents a value engineering analysis of project alternatives, identifies potential design exceptions, presents planning estimates, and provides a preliminary environmental evaluation. The product of this stage is the project initiation document.(2) Higher-level details of the project start to emerge at this step.

Project Clearance

At this stage, the project clearance documents are prepared. Engineering studies, project control surveys, environmental scoping, and environmental studies are performed. Public hearings are held on the environmental documents, responses to comments are prepared, and a preferred project alternative is selected. The products of this stage are typically the draft and final project approval report and the draft and final environmental document.

PS&E

Project PS&E are prepared at this stage, including the traffic plans and work zone traffic management plan to be employed during construction. All traffic analysis is complete at this stage.

Construction

The final stage of the project development process is the contracting and construction of the project. Supplemental traffic analysis may be performed at this stage to address issues that arise during construction. The agency's inspectors ensure that the traffic plans and construction traffic management plan are correctly implemented by the contractor.

Operation

Although not strictly part of the project development process, monitoring of the project's operation after it opens determines if the project operates as predicted by the traffic analyses conducted during the project development process. Lessons learned from monitoring project operation can be used to improve the traffic analyses performed during the project development process.

Each stage of the project development process requires different types of traffic analyses. At the early stages of the process, less is known about the project design and its likely opening date. As the various stages of the process are completed, more becomes known about the project design and its opening date. Thus, at the start, the traffic analysis must be more general, consider more alternatives, and employ more assumptions than at the later stages of project development (see figure 3).

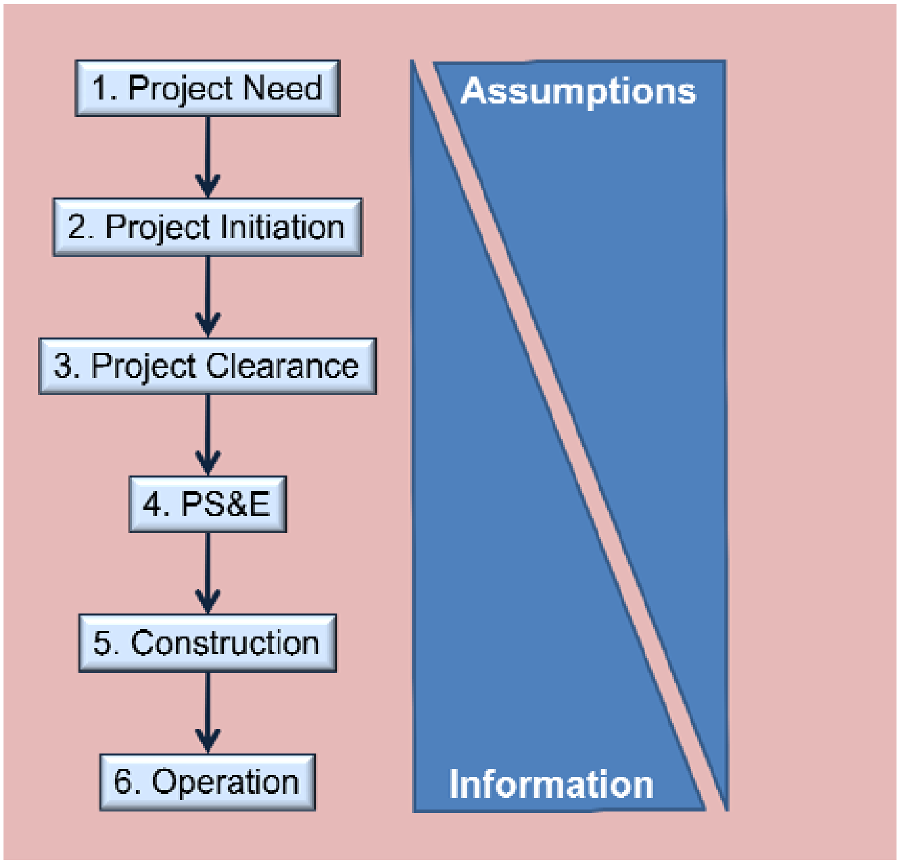


Figure 3. Chart. Information versus assumptions during project life cycle.

CURRENT PRACTICE

The project development process varies considerably among agencies in the United States, but each stage of the project development life cycle imposes the following general requirements for traffic analysis and the tools used to perform those analyses.

Project Need

Project need is usually determined by one or more planning studies. At this stage, traffic analysis tools best suited to planning (transportation planning models and sketch planning) are applied. The traffic analysis is focused more on predicting demands and capacities than on predicting precise operational conditions. The tools employed at this stage must be able to consider long-term development trends (10 to 30 years in the future), multimodal transportation, and highway capacity improvements over a very large network. The objective is to obtain an approximate size of the facility needs to its nearest number of lanes.

Project Initiation

At the start of this stage, the long-term need for a transit or highway capacity improvement and the approximate geographic location of the need have already been identified. The project initiation stage seeks to better define the project through conceptual design and alternatives analyses. The traffic analysis is focused on further defining the project need and the range of solutions available for addressing the need. The traffic analysis tools used at this stage still must be able to deal with a relatively incomplete project description and must be able to rapidly evaluate several conceptual alternatives. At this stage, the tool must provide a slightly more precise estimate of traffic performance but need not consider subtleties of the specific design. The traffic analysis tool at this stage generally assumes the facility is designed and operated according to agency standards. Design exceptions and specific operation strategies (such as ramp metering or signal optimization) are generally not evaluated until the next stage of project development.

At this stage, sketch planning and travel demand models are often used. Deterministic/analytic HCM-based tools may be used.

Project Clearance

At the project clearance stage, all design and operation details of the proposed project are known. The traffic analysis tool must be able to take into account the project's design and operation specifics. In addition, since the final environmental analysis is performed at this stage, the tool must be able to evaluate the traffic performance characteristics and the effects of alternatives to the project on the project itself and other affected facilities in the area to a degree equal to that of the project itself. The traffic analysis must be sufficiently accurate and geographically/temporally comprehensive to support air quality and noise analyses for the project. The traffic analysis must also include the effects of the project and its alternatives on the demand for the facility and other affected facilities. The project clearance stage is the most analytically intensive stage of the project development process.

At this stage, the full spectrum of tool types may be used: sketch-planning tools, travel demand models, analytical/deterministic HCM-based tools, optimization tools, and simulation models.

PS&E

The preparation of PS&E for a project generally requires analyses to support the preparation of traffic plans for the project and the preparation of traffic management plans during construction. Traffic management analyses may require off-facility analyses of adjacent streets if construction detours require the use of off-facility routes.

The primary tools used at this stage are analytical/deterministic HCM-based tools. Optimization tools and simulation models may also be used.

Construction

During construction, rapid-response traffic analyses may be required to identify solutions to unanticipated traffic handling issues that arise during construction. The primary tools used at this stage are analytical/deterministic HCM-based tools. Optimization tools and simulation models may also be used.

Operation

The operating agency employs traffic analysis tools to identify the appropriate control settings to apply to the facility traffic controls (e.g., ramp meters and traffic signals). The tools used at this stage are typically optimization tools designed to find the best control parameters for a given situation. The analyses must be accurate and precise to the conditions observed in the field and often require further fine-tuning in the field before the final control settings are put in place.

At this stage, optimization tools are primarily used. Analytical/deterministic HCM-based tools and simulation models may also be used.

The operation stage is a good opportunity for the agency to evaluate the accuracy of its forecasts of the project operation. A monitoring program for recently opened projects can provide valuable feedback for future project development analyses.

THE TRAFFIC ANALYSIS TOOLBOX

Figure 4 shows the general focus of each tool category. Sketch planning and travel demand models are focused on predicting major changes of demand at the system level. Travel demand models can also produce facility-specific results, but they are less accurate for that purpose. HCM tools and traffic control optimization models do not predict changes in demand. HCM tools are best suited for specific bottleneck analyses but have been extended to facility analysis freeways and urban arterials. Optimization models are generally focused on single-facility analyses. Simulation models cover a wide range of geographic levels and dwell with bottlenecks and facilities. They can also be used for system analyses, but practical considerations (coding and computation requirements) generally limit the size of the systems they can cover. Simulation models may do some limited demand forecasting (primarily route choice).

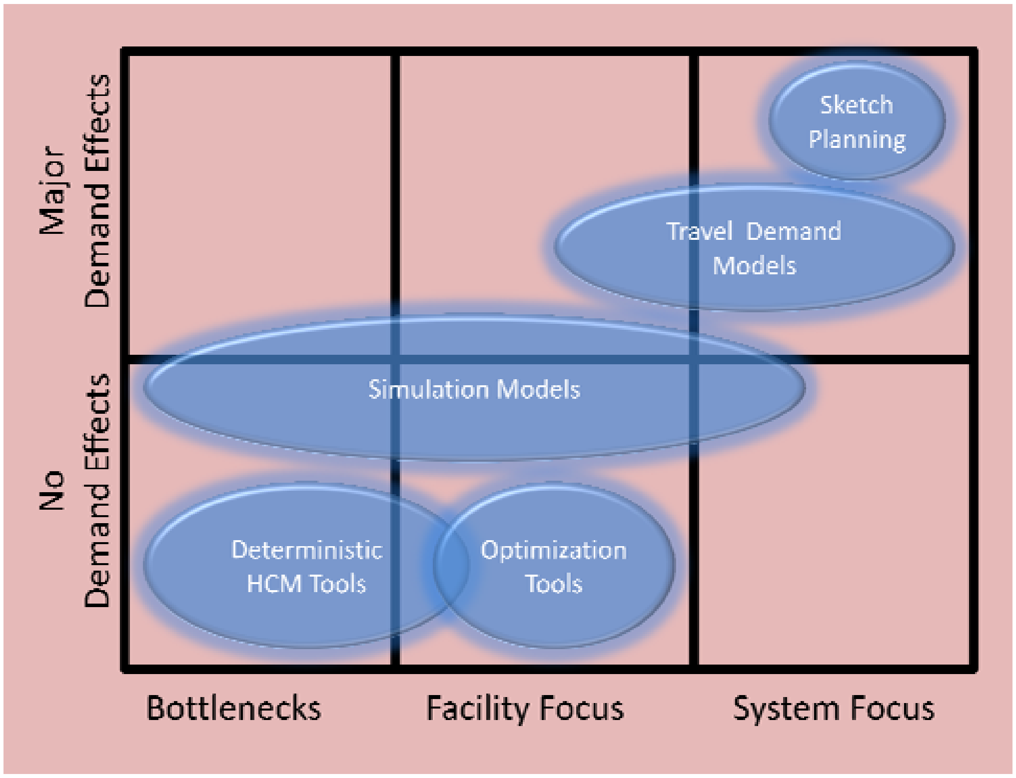


Figure 4. Chart. Geographic and demand focus of analysis tool categories.

Figure 5 characterizes the general resource requirements of each tool category and the degree of precision each tool delivers in terms of traffic performance predictions. Note that demand models focus their resources on demand modeling, rather than on traffic operations analyses. Thus, demand models typically require more resources than an HCM analysis but deliver poorer precision in the predicted traffic performance.

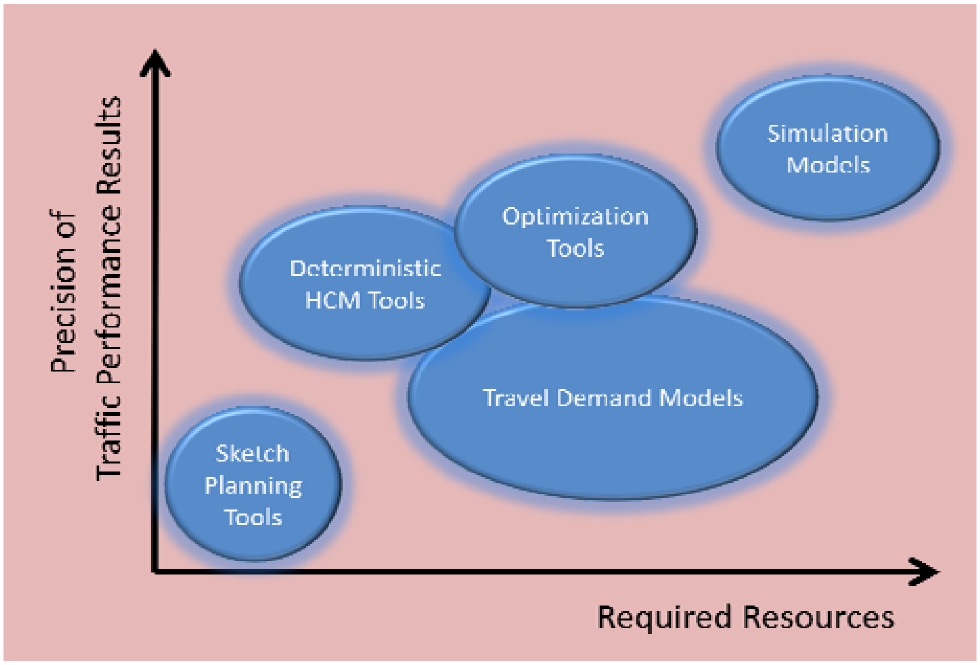


Figure 5. Chart. Resource requirements and precision of analysis tool categories.

The following descriptions of the major traffic analysis tool categories are adapted and condensed from *Traffic Analysis Tools Program, Volume I: Traffic Analysis Tools Primer*:(1)

- **Sketch-planning tools:** Sketch-planning methodologies and tools produce general order-of-magnitude estimates of travel demand and demand/capacity ratios in response to transportation improvements. They allow for the evaluation of specific projects or alternatives without conducting indepth engineering analyses. Such techniques are primarily used to prepare preliminary budgets and proposals and are not considered a substitute for the detailed engineering analysis often needed later in the project implementation process. Sketch-planning approaches are typically the simplest and least costly traffic analysis technique. Sketch-planning tools perform some or all of the functions of other analytical tool types, using simplified analyses techniques and highly aggregated data. However, sketch-planning techniques are usually limited in scope, analytical robustness, and presentation capabilities.

- **Travel demand models:** Travel demand models predict travel demand, specifically trip generation, destination choice, mode choice, time-of-day travel choice, and route choice as a function of land use patterns, socioeconomic data, and the transportation (road and transit) network. A great deal of resources are needed to create a demand model from scratch. Once established, demand models are inexpensive to utilize. Travel demand models were originally developed to determine the need for and benefits of major highway capacity or transit service improvements in metropolitan areas. They are not suited as well for evaluating travel management and operations management strategies such as intelligent transportation systems (ITS). Travel demand models sacrifice precision in traffic performance predictions in order to devote resources to travel demand analysis and to determine when demand exceeds capacity.

- **Analytical/deterministic (HCM-based) tools:** Most analytical/deterministic tools are based on the macroscopic, deterministic procedures of the HCM. These tools quickly predict capacity, density, speed, delay, and queuing as a function of demand, facility geometry, and facility controls. Analytical/deterministic tools are good for sizing facilities to avoid congestion but are less suited for distinguishing between different levels of severe congestion. They are able to analyze the performance of isolated or small-scale transportation facilities; however, they are limited in their ability to analyze the effects of queues on system performance.

- **Traffic control optimization tools:** Traffic control optimization tools usually combine an analytic/deterministic tool with an objective function and a search algorithm to optimize the signal or ramp meter control settings. In addition to the usual outputs of the analytic/deterministic tools, traffic control optimization tools output recommended signal or ramp meter timing plans.

- **Traffic simulation models:** Simulation models dynamically model facility traffic performance over an extended time period. For example, a simulation model may report traffic conditions every 5 min over the course of a 5-h analysis period. Microscopic simulation models move individual vehicles through the facility, store them upstream of bottlenecks, and may redirect them to less congested routes over the course of the analysis time period. Mesoscopic simulation models employ the same dynamic time-slice method of moving vehicles through the network as microsimulation models but employ the volume-speed-density relationships of analytic/deterministic models to estimate facility segment traffic performance. Data collection needs, computer time, and storage requirements for simulation models are much larger than for deterministic/analytic models, usually limiting the network size and the number of simulation runs that can be completed.

Challenges to Consistent Analysis of Transportation Projects

The major challenges to the consistent analysis of transportation projects during their development life cycle are as follows:

- The often lengthy elapsed time between project initiation and delivery.

- The fact that no single tool will carry the analyst through the entire project development cycle.

- The varying capabilities and limitations of each traffic analysis tool type.

- The extensive training and experience necessary to apply each tool type, which often means that different analysts and sections of the organization may be involved in different stages of the project development process.

The proper application of each traffic analysis tool type is a challenge in its own right. Major causes of erroneous results include the following:[(1)]

- Overuse of defaults rather than field data.
- Failure to calibrate the tool sufficiently.
- Failure of the tool to accurately predict queues.
- Geometrics outside the range of the tool type.
- Inaccurate data given to the tool.
- Inaccurate demand forecasts given to the tool.
- Inaccurate origin-destination information.
- Failure of the analyst to check the results for reasonableness.
- Counting discharge volumes in the field instead of demand.
- Different definitions of level of service between tool types.

Why is Consistency Important?

Consistency in traffic analysis results throughout the project development life cycle is fundamental to quality. Throughout this document it is maintained that consistency flows from a focus on quality.

Obtaining consistent analysis results from project planning through project design ensures there are no surprises to undermine project delivery. Consistency offers benefits in terms of cost and time savings for the project delivery process as each succeeding stage of project delivery builds on the technical analysis from the previous stage. Naturally, the pursuit of consistent traffic analysis is an important means to achieve overall agency quality, enhancing the agency's credibility and effectiveness.

The main benefits of consistent analysis throughout the project development life cycle are as follows:

- Analysis cost and time are reduced because repeated effort is not needed.
- Analysis results can be refined and reapplied based on the results of prior studies.
- The project analyses enjoy a longer shelf life.
- The credibility of analysts, managers, and the project development process as a whole improves.
- Agency decisionmaking is more effective and consistent.

What Can Be Achieved?

While consistency is a commendable goal and a major component of an agency's effort to achieve quality of technical analyses, there is a limit to how much consistency can and should be achieved over the course of a project development life cycle.

When an agency starts the project development cycle, relatively little is known or defined for the project. Indeed, one of the major purposes of the project development process is to define those initially unknown details for the project. Thus, even if the agency were somehow able to employ the same tool and assumptions throughout the project development process, there would still be changes to those assumptions as the agency decides on the details of the project.

Secondly, the project development process is not instantaneous. The agency is unable to freeze its own work or that of other agencies in the area while it goes through the project development process. Thus, as other agencies develop new socioeconomic growth forecasts and make major decisions about projects, the agency will find that the assumptions it started with will rarely be current when the agency reaches the project clearance stage. Indeed, for some projects, changes in socioeconomic growth assumptions may occur over the course of the project clearance stage itself.

Thus, the goal of achieving and maintaining consistency throughout the project development process cannot be to maintain the same precise numerical results throughout the project development process. Instead, the goal should be to ensure that the initial decision to proceed with the project (as the details of the project are further refined during the process) is still the correct choice at the end of the process.

The goal of achieving consistent traffic analysis results in the project development process is to identify and adopt assumptions and traffic analysis procedures that are robust in the face of refinements to the project design and changes in rest of the world while the development process proceeds. If the project initiation stage is performed correctly, then the decision to proceed with project development should not be contradicted by the traffic analysis results at the project clearance stage.

An important feedback to the agency on the quality of its project development process is the operation of the project once it is opened. The performance of the facility should be as predicted during the latter stages of the project development process. If there are surprises when the project opens, then the agency needs to reconsider the tools and assumptions employed during the project development process.

CHAPTER 3. CREATING A PDAP

The project development process is a long and complex process involving many analysts, many stakeholders, and many analysis tools. The process is a complex system in which the objective of the agency is to manage the risk inherent in the project so as to deliver the project on time and within budget. The way to manage risk is to take it explicitly into consideration in the development of an overall analysis plan for delivering the transportation improvement project. Thus, it is recommended that, at the project initiation stage, the agency develop an overall scope, approach, budget, and timeline for delivering the project. This plan is the PDAP.

Readers familiar with systems engineering will recognize the PDAP as performing the same function as a systems engineering management plan.(3) In fact, training in systems engineering is very useful in accomplishing the recommendations of this chapter.

BASIC TECHNICAL ANALYSIS SCOPING ISSUES

Scoping and budgeting a traffic analysis include the same basic issues and tensions typical of any work-scoping effort. There is the perpetual tension between the ideal and the achievable. The decisionmakers want it all, but they only allow the manager a certain amount of time, budget, and resources to deliver the analysis. The manager must find an approach to the technical analysis that gives the decisionmakers the best information possible within the available resources.

Technical analysts often think of time as their friend, asking for more whenever they can, but time is the enemy of good technical analysis, the enemy of consistency, and, ultimately, the enemy of project delivery. While a minimum amount of time is required to perform an authoritative and accurate technical analysis, the world does not stand still while the analysis is conducted. Conditions change, assumptions become outdated, decisionmakers change, and even technical analysts change. The decisionmaking value of a technical analysis has a limited shelf life, decaying in value from the day the analysis is initiated.

Another basic fact often missed in the development of a PDAP is the necessarily evolving nature of the project as it proceeds through the project analysis process. What starts out as a straightforward high-occupancy vehicle (HOV) lane project may turn into a high-tech congestion pricing (high-occupancy toll (HOT) lane) project by its end. An interchange reconstruction may expand to include auxiliary lanes and ramp meters. Funding constraints may rule out key project components as cost estimates are refined. While not all changes can be anticipated, the PDAP must employ tools and methods that can be readily adapted or expanded to the evolving project description. Ideally, the manager leaves a reserve in the PDAP both in terms of time and budget to absorb the surprises that inevitably arise during the project development process.

Finally, the project needs and purpose will evolve as technical analyses are completed and as the various stakeholders participate in the process. The tools and procedures identified in the PDAP need to be flexible and general enough to accommodate these changes.

Developing the PDAP is all about managing the risk and complexity of a multistage, multitool project delivery process with evolving project needs and description in a changing world that often threatens to render earlier decisions and assumptions obsolete.

CONTENT OF THE PDAP

The PDAP is the agency's opportunity to coordinate how the project is evaluated and to maintain consistent analyses throughout the project development life cycle. It is the master scope and the scalable scope for all subsequent technical analyses of the project and its alternatives. The PDAP should cover the following topics:

- Conceptual project description.
- Objectives of traffic analysis.
- MOEs.
- Traffic analysis approach.
- Risk management plan.
- Resource requirements.
- Schedule.

Conceptual Project Description

The conceptual project description summarizes the project need and purpose, describes the overall concept for the project, describes possible project alternatives, and identifies the facilities and agencies likely to be affected by the project or its alternatives. Much of this material is a summary of the contents of the project initiation document. The purpose of summarizing this information in the PDAP is to establish the context for the traffic analysis objectives and the scope for the analysis.

The conceptual project description should attempt to bind the feasible range of conceptual alternatives and the likely effects of the project and its alternatives. The manager should slightly overestimate the likely geographic and temporal effects and let the subsequent technical analyses narrow the range of feasible alternatives and the expected range of effects.

Objectives of Traffic Analysis

The goals and objectives of the traffic analysis identify the questions that the analysis will need to answer and the required detail of the answers. The goals describe the general traits of the project (e.g., reduces congestion) while the objectives identify quantifiable measures of project performance (e.g., reduces delay to agency standards). The objectives should cover all stages of the project development cycle but may vary for each stage of the analysis. For example, in the early project initiation stage, the analysis may be focused more on identifying the demands to be served by the conceptual project and its general performance in comparison to the feasible alternatives and less on the specific details of the project's operation. Later in the development process, the focus is on pinning down the design details of the project and understanding in more detail the precise operational performance of each component of the project.

MOEs

In this section of the PDAP, the manager identifies the MOEs to be generated by the traffic analysis at each stage of the project development process and how the results of the analysis will be presented to decisionmakers and the general public. The MOEs are the numerical outputs of the traffic analysis that address the specific objectives of the project. Examples of typical traffic MOEs include delay, stops, queues, speed, density, and travel time. These measures may be aggregated into vehicle-miles traveled (VMT), person-miles traveled (PMT), vehicle-hours traveled (VHT), or person-hours traveled (PHT). The MOEs may vary to address the objectives of each stage of the project development process. (MOEs and the presentation of analysis results to decisionmakers and the general public are covered in more detail in subsequent chapters.)

Traffic Analysis Approach

The overall traffic analysis approach is described in this section. Where feasible, the specific tools, assumptions, and parameters are specified for each stage of the project development process. The approach describes how the tools, assumptions, and parameters will be coordinated between tools and analysis stages. (This topic is covered in more detail in chapter 5.)

Risk Management

In this section, the manager identifies the risks to successfully completing the analysis on time and within budget. Risks can include changes in project purpose, changes in project concept, personnel changes, stakeholder changes, changes in assumptions driven by changes in the real world, advances in tools, agency unfamiliarity with specific tools, etc. For each risk, the manager describes the planned course of action to overcome the risk (fallback analysis approach) and the point in the analysis process when a go/no-go decision must be made.

Resource Requirements

This section identifies the personnel and budgetary requirements for each stage of the analysis.

Schedule

This section identifies key milestones, delivery dates, critical path, and risk management decision points for each stage of the analysis.

DEVELOPING THE PDAP

Many agencies may have a standard PDAP already in place. It may exist under a different name, such as a Project Development Procedures Manual, and may cover a broader range of project delivery tasks than simply traffic analysis. If such a manual is already in place, then the duty of the manager charged with project delivery is to tailor the general guidance provided in the agency’s manual to a specific traffic analysis plan for project delivery.

This section focuses on the specifics of scoping the overall traffic analysis plan for project delivery. As such, it may be helpful to agencies that already have a project delivery procedures manual because this section will address traffic analysis specifics that may not be covered in sufficient detail in a broader manual.

The steps for developing the PDAP are as follows:

1. Identify stage-specific traffic analysis goals and objectives.
2. Assess agency capabilities and resources.
3. Set a project delivery schedule.
4. Develop a first draft technical analysis approach by stage (MOEs, tools, assumptions).
5. Assess risks to successful completion of analysis.
6. Identify key decision points for employing fallback technical analysis approaches.
7. Get commitments from analysts that will be performing the analyses.
8. Prepare PDAP.

These steps are shown in figure 6 and discussed in more detail in the following sections.

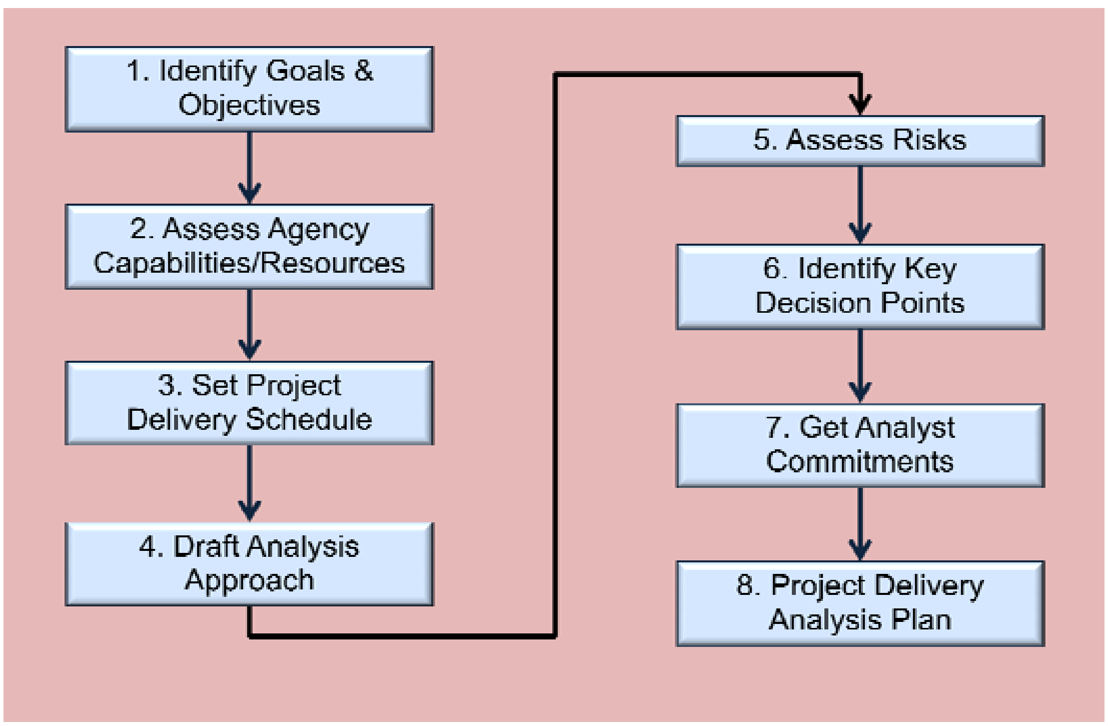


Figure 6. Chart. Steps to development of PDAP.

Identify Analysis Goals and Objectives

There will be a set of overall goals and objectives for project delivery. These will naturally follow from the project need and purpose statement. However, the manager should also identify specific analysis goals and objectives for each stage of project delivery.

For example, a project needs and purpose statement may read, “The section of highway X fails to meet agency standards for safety, pollutant emissions, and traffic operations.” The project then has the following purposes:

- Reduce peak period congestion and delay.
- Encourage HOV and transit use.
- Support regional air quality goals.
- Improve safety for motorists and department maintenance personnel.

While the goals for the project may be fairly general, it is desirable to refine the project goals as the project analysis proceeds to specific, measureable objectives. By the end of the analysis, the project objectives should be SMART: Specific, Measurable, Agreed upon, Realistic, and Time-bound.

The goal of the PDAP for the project is distinct from the goals and objectives of the project. The goal of the PDAP is to provide the data necessary to determine the design of the most cost-effective project for achieving the project purpose within budgetary and environmental constraints relevant to the project. This overall goal for the PDAP is achieved in stages.

At the project initiation stage, the objective is to better define the conceptual project design and alternatives. Therefore, the goal of the traffic analysis at this stage is to identify the feasible range of solutions to address the identified project need. The analysis should be robust enough to not overlook a feasible solution that is potentially superior to the proposed project. The traffic analysis objectives of the project initiation stage are usually to rapidly evaluate a variety of solutions using tools that do not require a great deal of detail on the specifics of the project design or its alternatives.

At the project clearance stage, the objective is to develop the project design and operation details, secure environmental clearance, and obtain management approval to proceed to PS&E. The objective of the traffic analysis at this stage is to provide data in support of project design and environmental analysis. The traffic analysis does not have to determine the precise signal control or ramp meter settings, just demonstrate it is feasible for the agency to operate the facility with the proposed design, within the expected range of demands, and within its target performance standards.

At the PS&E stage, the objective is to prepare the construction drawings and bid documents. The objective of the traffic analysis is to support the development of those documents, primarily the traffic plans (signals, signing, and striping) and the traffic handling plans during construction. The focus of the traffic analysis is on adapting the project clearance traffic analyses to the needs of traffic handling during construction as well as the design of the facility. Adequate turn pocket and ramp storage lengths must be designed so as not to unduly constrain the agency’s flexibility to employ a range of signal and ramp control strategies. The work zone traffic management plan is developed at this stage.

During construction, the objective is to rapidly and cost-effectively construct the project with minimal adverse effects to the public and construction workers during the construction period. The traffic analysis is focused on safely and rapidly responding to conditions as they arise in the field.

Operation of the facility involves periodic updates of the facility control strategy and control settings in response to changes in demands and operating conditions. The traffic analysis is focused on day-to-day operating conditions.

Assess Agency Capabilities and Resources

The next step in the development of the overall PDAP is for the manager to assess the resources available for the analysis. This includes identifying personnel with proper training and experience and the analysis tools with which the agency has had extensive experience. The way to minimize risk in the analysis and delivery of a project is to use the tried and true tools and personnel that the agency regularly uses for traffic analyses.

Set Project Delivery Schedule

The project delivery schedule should be set based on the manager's experience for each stage of the process. The scheduled time should be sufficient to complete an accurate analysis. Assumptions, costs, laws, decisionmakers, and analysts all change with time. The analysis schedule should be as tight as possible while still providing sufficient time to deliver accurate results for each stage of the analysis.

The schedule should include key checkpoints and decision points throughout the analysis. The checkpoints (often milestones) are for the manager to assess progress and determine if additional resources are required to meet the schedule. Decision points are where the manager must decide if the current analytical approach is not going to be successful and it is time to switch to a backup approach.

Develop Draft Technical Analysis Approach by Stage

The surest way to deliver a project analysis on time and within budget is to use the traffic analysis tools and personnel with which the agency is already experienced. The traffic analysis approaches used in each stage of the project delivery process should use the agency's tried and true tools and experienced personnel as much as possible. Note that the phrase "tried and true" means that the proposed analysis approach should satisfy two criteria. The agency should be experienced with the proposed approach (tried), and the agency should have verified that the proposed approach, when applied in the past, has yielded good (true) results.

While it is tempting to try a new tool or analysis technique, research and project delivery should be kept entirely separate. Project delivery is usually under a strict time schedule, where each month's delay is an increase in the cost of the project and an added threat to the technical value of the analysis for decisionmaking. The world does not stand still. A delayed analysis may be rapidly rendered obsolete by changes in the world.

A manager should not fear sticking with tools and analysis approaches the agency is familiar with. A dumb tool in the hands of a smart engineer can still produce technically useful and valid results. It is rare when a smart tool in the hands of a dumb engineer can do the same. Save staff training and the testing of new tools for a research project where time is not constrained and the agency can afford the mistakes that invariably come with learning a new tool. Project development, with the cost implications of delays, is usually not the best time for an agency to embark on research and training to improve its traffic analysis capabilities.

Note that an old tool that is new to the agency is a new tool as far as project delivery purposes are concerned. In such a situation, the manager should build into the PDAP the borrowing of expertise from other agencies, universities, or consultants to advise staff on the use of a tool that is new to the agency.

Some ways to deal with uncertainty created by new tools and new procedures are as follows:

- Borrow expertise from other agencies/sources.
- Incorporate a back-up parallel analysis using tried and true tools/procedures.
- Sponsor research.

When employing a new tool or analysis procedure, the manager may also build into the PDAP a parallel analysis, where a known older tool is used in parallel with the new tool. As the analysis proceeds, the manager cross-checks the new and old tool results (to verify that the new tool is applied correctly), and when confidence is built up with the new tool, the old tool is abandoned. The old tool provides backup in case the new tool does not perform as expected or requires more resources than expected. Project delivery is not threatened by unexpected glitches in the new tool.

Although tried and true are the keys to successful project delivery, the manager can still be confronted with projects that are new not only to the agency but often to the profession as a whole. Congestion pricing and speed harmonization are examples of cutting-edge projects for which a manager may be called on to develop a PDAP and for which the agency has no experience. In such a situation, research is the only course of action. The PDAP should be scheduled and budgeted accordingly, recognizing that there will be surprises along the way.

The FHWA Resource Center's staff and Web site are good sources of information and expertise on new and innovative technologies and analysis tools.(4)

More specifics on the technical approach relevant to the selection of MOEs and to the selection of tools, parameters, and assumptions for consistent analyses are given in the following chapters.

Assess Risks

The manager has no doubt already taken into account the risks of the various stages of the project traffic analysis when the draft technical approach was developed. However, the purpose of this step is to secure input from the technical analysts and supervisors who are responsible for performing the actual analyses. These people can best communicate the risks of the proposed technical analysis approach and suggest options for overcoming them. If outside agencies are involved in the analysis or the review of the analysis, it would be useful to obtain their input as well.

Identify Key Decision Points

For each significant risk identified in the risk assessment, the manager should develop a fallback plan with an alternate approach for completing the analysis on time and within budget. The manager should also identify a decision point (date) and criterion for determining when the analysis must switch to the fallback approach.

Get Commitments from Analysts Performing the Analyses

Key to the success of the PDAP is securing commitments from the analysts and their supervisors to perform the analyses called for in the PDAP. If the analyst or supervisor is not happy with the proposed approach or tools, this is the time to find out.

Revise Technical Analysis Approach and Prepare PDAP

With the commitments from the analysts in hand, the manager should revise the PDAP and deliver a copy to each team member.

CASE STUDY—DEVELOPING THE PDAP

This section illustrates the development of the PDAP, a scalable multistage traffic analysis scope, using a hypothetical case study. The selected case study is a project to add HOV lanes to 13 mi of interstate freeway. One option to be considered is to convert the HOV lanes at a later point to HOT lanes with various ITS infrastructure improvements to support their operation.

The project needs analysis established the following purposes for the project:

- Reduce peak period congestion and delay.
- Encourage use of HOV and transit.
- Support regional air quality attainment goals.
- Improve safety for motorists and agency maintenance workers.

Establish Traffic Analysis Objectives

Every traffic analysis has the following basic goals:

- Provide analytical results on the effects of the proposed project and its alternatives.
- Communicate the results in a meaningful form to decisionmakers.

The specific traffic analysis objectives for the PDAP for this case study are taken from the project needs and purpose statement. The traffic analysis should produce analytical results on the effects of the proposed project and its alternatives on the following:

- Peak period congestion and delay.
- HOV and transit use.
- Regional air quality.
- Safety for motorists and agency maintenance workers.

The selection of specific MOEs to measure achievement of the project objectives is discussed later.

Assess Agency Capabilities

In this particular case study, the manager developing the PDAP found that his or her agency's district staff is familiar and experienced with travel demand forecasting and highway operations analysis using HCM techniques. The district staff is less familiar with microsimulation and has no experience with the evaluation of the traffic operations effects of ITS or HOT lanes.

The manager developing the PDAP noted that the requisite microsimulation expertise nevertheless resides within the agency at headquarters and in two other districts. The PDAP identified these as options to support the local district staff.

The PDAP noted that agency staff is generally unfamiliar with methods for evaluating the effects of ITS and management strategies on traffic operations. The HCM does not address ITS improvements, and microsimulation models require significant staff resources to evaluate such improvements. However, FHWA sponsored the development of ITS Deployment Analysis System (IDAS), a sketch planning program to assess the costs and benefits of ITS improvements, and was identified by the manager as a resource to advise the agency on the evaluation of ITS and HOT lane improvements.

Project Delivery Schedule

The PDAP set the project delivery schedule and identified the tools, resources, and technical approach to deliver the traffic analyses within the target schedule.

Draft Technical Analysis Approach (MOEs, Tools, Assumptions)

The technical approach of the PDAP identifies the MOEs and tools to be used in the analysis (discussed in later chapters). General guidance (and bounds to the extent feasible) is provided in the PDAP on assumptions and parameters. However, the manager should resist the urge to put the analyst in a straightjacket of specific parameters and assumptions. Conditions evolve, and it is necessary to allow sufficient flexibility to react to changes while still preserving the overall consistency and validity of the analyses.

The MOEs appropriate for the analysis objectives were selected, as shown in table 1.

Table 1. MOEs for HOV/HOT lanes case study.

Analysis Objective	MOEs
Reduce of recurrent and non-recurrent congestion	• Reduction in average peak period travel times • Improvement in average peak period speed • Improvement in level of service
Encourage HOV and transit use	• Change in HOV's share • Change in daily transit boarding
Support regional air quality attainment goals	• Reductions in regional vehicle emissions
Improve safety for motorists and agency maintenance workers	• Reduction in expected collision rate • Reduction in typical collision rate during construction

In this case, while non-recurrent congestion is indeed a component of total congestion, the PDAP manager concluded that the tools available to his or her staff did not enable a reliable estimate of non-recurrent congestion, so the manager selected MOEs only for recurrent congestion.

As explained in later chapters, after the appropriate investigation into the strengths and weaknesses of the available tools and technical analysis approaches, the manager determined that, in this case, the combination of a macroscopic sketch planning tool (such as IDAS), a travel demand model, an HCM model of the freeway, and an HCM-type model of the street arterials would be the most cost-effective option for delivering the traffic analysis on schedule and budget.

Dynamic traffic assignment (DTA) was considered to improve the accuracy of the travel demand model forecasts; however, this tool was rejected for this project analysis because the travel demand model had not been validated for DTA and because the agency lacked in-house expertise in DTA. A new travel model validation would have been required, triggering a significant increase of resource requirements for the analysis.

The scope, budget, and schedule for the traffic analysis was developed according to the stated conclusions.

Risk Assessment

Risk assessment and the strategies to manage that risk are project and agency specific. Usually, if the analyses can be completed within a year then the greatest risks are as follows:

- Changes in project design to save on costs or reduce environmental impacts.
- Analysis errors.
- Failure of analysis tools (and/or analysts) to perform as expected.

The methods to manage risks associated with changes in project design are as follows:

- Do not start analysis until a sufficiently specific design is agreed on. If necessary, start with several agreed-upon design alternatives.
- Employ analysis tools that can quickly respond to changes in project design.
- Communicate frequently with the design team and the environmental assessment team regarding potential changes in project design. Communicate interim traffic operations results that suggest where refinements in project design might be appropriate.
- Employ conservative assumptions regarding the demand for and the capacity of the project.

The methods to deal with analysis errors are typical quality assurance/quality control techniques, as follows:

- Independent peer review of each stage of the technical analysis.
- Reasonableness checks.

The methods for dealing with tool performance problems are as follows:

- Do not use tools the analytical staff is unfamiliar with.
- Call in outside experts, the software vendor in particular, for support. The FHWA Resource Center is a good source for expert advice.[4] Universities and suitably experienced consultants can be another source of expertise.
- Have a backup tool and analysis approach ready should the selected tool fail to perform as expected. Set a date for deciding whether to switch tools.

For analyses taking longer than a year, additional risks include the following:

- Changes in regional growth assumptions.
- Changes in funding.
- Changes in tools.
- Advances in road technology.
- Changes in personnel (technical, stakeholder, or decisionmaker).
- Changes in project purpose.

The long-term risks are harder to manage. The key is to complete the technical analyses expeditiously so as to not confront these long-term threats to consistency. For longer technical analyses, the following are some techniques that might be useful for reducing the impact of changed conditions:

- If the regional growth forecasting schedule is known, try to get advance information on the general magnitude of the changes and their timing. Then, try to incorporate them into the technical analysis through a sensitivity analysis.
- Changes in funding usually mean reductions in project scope, delays in implementation, and splitting of the project into stages. These risks can be reduced by using tools that can be quickly modified to reflect changes in project design and scheduling. The forecast year for evaluating the project can be extended 5 to 10 years to allow for uncertainties in project construction year.
- Changes in tools can be best managed by resisting the temptation to change (or update) tools in the middle of the analysis. Unless the updated tool fixes a bug known to affect the project analysis results, it is usually best to stick with the original tool and not risk introducing inconsistent results midway through the analysis process.
- Advances in road technology are difficult to anticipate. When the HOV project was initiated, congestion pricing was untested in the United States. The manager should keep abreast of the latest developments and incorporate sensitivity testing to address technology improvements

that may affect project design. FHWA maintains several Web sites that are useful for keeping abreast of technology changes.

- Changes in personnel are generally impossible to predict but are best managed by ensuring that more than one person is involved in each critical stage of the analysis. Appropriate support staff, decisionmakers, and stakeholders should be identified as potential successors and kept informed of study progress, purpose, and key decisions.

- Changes in project purpose, like technology changes, are difficult to anticipate. The best approach is to select a general purpose and comprehensive MOEs and tools that can respond quickly to changing project objectives.

Key Decision Points

Key decision points should be related to the delivery dates for key milestone results. The decision points should occur early enough in each task so the manager has a reasonable chance of delivering the analysis on schedule using an alternative approach but late enough so the manager is not needlessly changing analysis approaches when the original approach still has a chance to deliver the desired results on time.

The key is to identify when a tool (or an analytical approach) is not going to live up to expectations. It is always a difficult choice because one never knows if they are just one fix from having a successful outcome. If one has the resources, one can start a second team on the backup approach while the primary team continues to resolve problems with the preferred tool. The manager then lets the “best” team win, reporting on the approach that delivers the results on time.

Commitments

The best scope of work is useless unless the people implementing it are committed to it. The manager developing the PDAP should seek commitments from the technical analysts and their supervisors to the objectives, approach, schedule, and budgets for the analysis.

Prepare PDAP

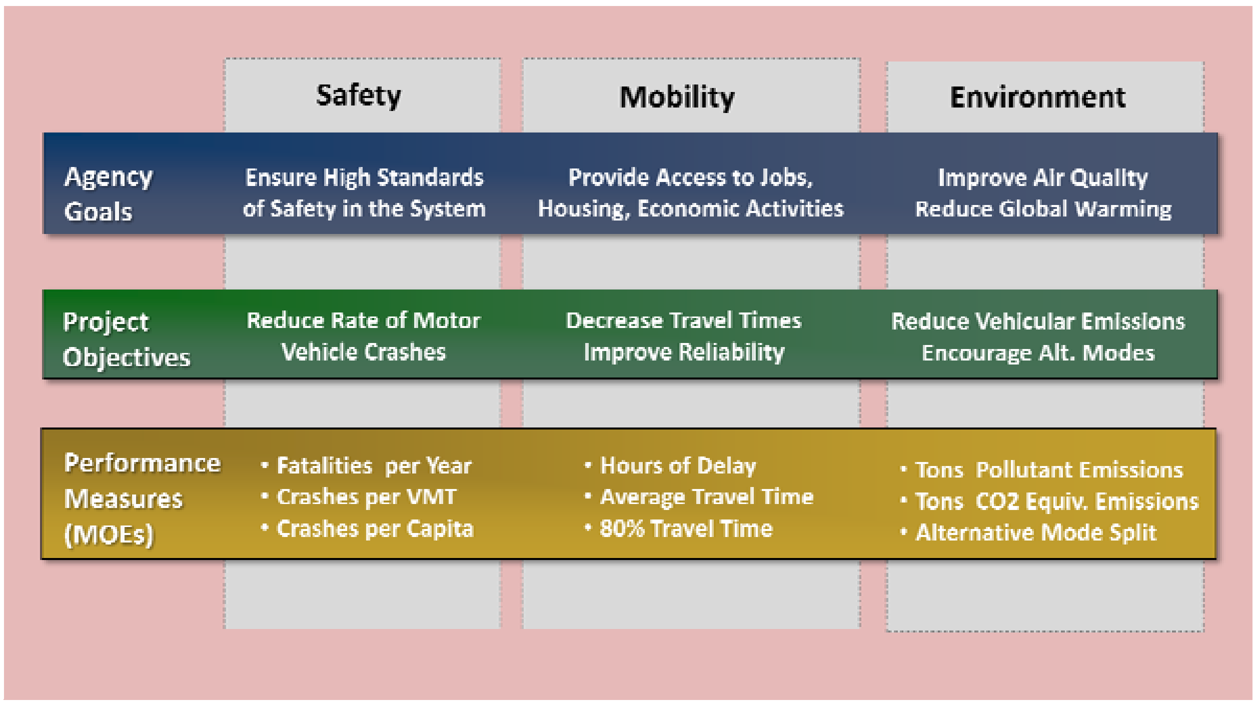
The PDAP should be prepared and delivered to all involved parties.

CHAPTER 4. SELECTING CONSISTENT MOES

Performance measurement through quantifiable MOEs is not an end unto itself. Rather, MOEs are used to determine the extent to which the proposed project and its alternatives meet the project need and purpose. MOEs should be selected prior to selection of the analytical approach and tools because they are critical to determining the extent to which project objectives have been achieved.

RELATING MOES TO PROJECT PURPOSE

MOEs should not be selected in a vacuum. They should be related to the purpose of the project and the general goals of the agency. Figure 7 shows how the selected MOEs can be related to the project objectives and how the project objectives can be related to broad agency goals. The relationship is much like a pyramid, starting at the top with a few goals related to specific topics (safety, mobility, environment, etc.). One or more project objectives may then be related to that goal. Several MOEs are typically required to determine the degree to which the proposed project meets its objectives.



Note: Figure shows only exceptionally brief summaries of project objectives. Actual objectives would be more specific.

Figure 7. Chart. Relationship of agency goals, project objectives, performance measures, and MOEs.

TYPOLOGY OF MOES

There are a wide variety of MOEs available to the manager and analyst. In regards to traffic performance measurement, the MOEs fall into seven broad categories: measures of utilization, travel time, delay, speed, stops, queues, and density (see table 2).[1] In addition, there are traffic-related MOEs, collisions, and emissions, which address safety and the environment.

Table 2. Typology of MOEs.

MOE Type	Bottleneck and Facility-Specific	System Measures	Indices of Performance
Utilization	Vehicles per hour, V/C or D/C	PMT, VMT	V/C or D/C, level of service
Time	Mean travel time, 80 percent travel time	PHT, VHT	Travel time index, planning time index
Delay	Mean delay/vehicle	PHD, VHD	Level of service
Speed	Mean	VMT/VHT, PMT/PHT	Percent free-flow speed, level of service
Stops	Mean stops/vehicle	Total stops	Probability of stopping
Queue	Mean, 95 percent	Stopped delay	Queue storage ratio
Density	Mean	N/A	Level of service
Collisions	Collisions/million VMT (or per million vehicles)	N/A	Actual/typical facility rate
Emissions	Tons/day	Tons/day	N/A

Notes: V/C and D/C are the volume/capacity ratio and demand/capacity ratio, respectively. PMT, PHT, and PHD are person-miles traveled, person-hours traveled, and person-hours of delay, respectively. VMT, VHT, VHD are the vehicular equivalent of the person measures. The queue storage ratio is the ratio of the predicted queue length to the available storage length. N/A indicates not applicable.

Each MOE type, such as measures of utilization, is expressed differently depending on whether the focus is on a specific facility or on the system. In the case of measures of utilization, the MOEs for a specific facility may be vehicles per hour, volume/capacity ratio, or demand/capacity ratio. At the system level, it is typical to aggregate these facility-specific measures into accumulated PMT or VMT. Measurements of volume/capacity ratio are generally of little value at the system level because all transportation systems have a great deal of spare capacity when considered as a whole. For the same reason, average volume/capacity at the facility level is of less value than the maximum volume/capacity ratio at any bottleneck in the facility.

Each type of MOE can also be expressed in the form of an index relating the MOE to some target standard value. The purpose of the indices is to facilitate communication of the quality of the performance (good, OK, bad) to decisionmakers less familiar with typical or acceptable values for the MOE. In the case of measures of utilization, the usual index is the volume/capacity ratio or the demand/capacity ratio. The demand/capacity ratio is usually preferable because it provides better information than the capacity-constrained volume/capacity ratio. Volume, being a counted value in the field, cannot exceed the physical capacity of the bottleneck. A maximum bottleneck demand/capacity ratio below 1.00 suggests the facility has spare capacity. The ratios may be supplemented with a letter grade, A–F, indicating the level of service.

More on MOEs and performance measurement in general can be found on the following FHWA sites:

- Operations Performance Measurement Program: http://ops.fhwa.dot.gov/perf_measurement/index.htm.[5]
- *Traffic Analysis Tools Program, Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness*: http://ops.fhwa.dot.gov/publications/fhwahop08054/index.htm.[1]

In the remainder of this chapter, the basic traffic performance MOE types are discussed with the intent that when each category of MOE is mentioned, the category includes all of the facility-, system-, and index-specific variations within each MOE type identified in table 2.

TYPICAL MOES BY STAGE OF ANALYSIS CYCLE

While the project purpose is constant throughout the project development life cycle, the purpose of the traffic analysis varies slightly at each stage. Thus, the MOEs will vary in order to address slightly different analysis objectives at each stage.

Project Initiation Stage MOEs

At this early stage of the project development cycle, the analysis objectives are to develop a conceptual design for the project and to sketch out possible alternatives. The focus is on rapid analysis considering system effects, with details of the project to be determined at each stage of project development. The temporal focus is primarily 20 years or more in the future. The MOEs to support the conceptual design process are generally system MOEs to ensure the project is achieving its purpose and facility MOEs to aid in sizing the project. As shown in table 3, the MOEs that are appropriate at this stage of the analysis include PMT, PHT, person-hours of delay (PHD), VMT, VHT, vehicle-hours of delay (VHD), mean speed, collision rate, and tons of emissions.

Project Clearance Stage MOEs

At the project clearance stage, the objective is to develop a preliminary design for the project in sufficient detail to enable comparison of its benefits and environmental impacts to those of its alternatives. The MOEs appropriate at this stage of analysis are primarily facility-specific MOEs, with some system MOEs to aid in the environmental analysis. The temporal focus is both short-term (construction and opening day of project) and long-term (25 years after project completion). The project clearance stage involves communication of the analysis results with decisionmakers and stakeholders as well as with the general public. Thus, there is heavy use of index MOEs, such as level of service, to make it readily apparent to the non-technical person whether the performance will be acceptable or not. As shown in table 3, the MOEs that are appropriate at this stage of the analysis include volumes, demand/capacity ratios, mean travel time, level of service, mean speed, collision rate, and tons of emissions.

An emerging issue for project analysis is to identify measures of facility reliability, such as the expected 80 percentile (or other percentile) highest travel time for the facility. For the convenience of communicating the results to decisionmakers, reliability may be expressed in terms of the planning time index, the ratio of extra time required to the off-peak free-flow travel time to ensure that the driver arrives on time with a certain degree of certainty (e.g., 95 percent).

PS&E Stage MOEs

At the PS&E stage, the focus is on project design details. The MOEs at this stage are focused on the specific design elements of the project and not the overall facility. MOEs sensitive to project design details (segments, intersections, merge, diverge, etc.) are critical at this stage. As shown in table 3, the MOEs that are appropriate at this stage of the analysis include volume/capacity ratios, level of service, and the queue storage ratio. The objective of project design is usually to ensure that the facility is sized to handle the forecasted demands. In this situation, the demands are constrained by the capacities of the facilities feeding the project. The project is designed to serve the volumes that can arrive at the project site, not the potential demands that might arrive if the surrounding infrastructure was improved.

Construction Stage MOEs

During construction, the focus is on safely moving traffic through or around the construction site. A certain amount of temporary delay and queuing is expected. The focus is less on achieving a specific traffic performance objective than on the best possible setup within the constraints of safely constructing the project.

As shown in table 3, basic MOEs are appropriate at this stage of the analysis to facilitate rapid computation when dealing with construction traffic handling and detours. They include volume/capacity ratios, delay, and queue storage ratios. Most other MOEs were already computed and evaluated during the PS&E stage when the construction traffic plans were developed.

Operations Stage MOEs

Once a facility is open and operating, the focus returns to obtaining the best possible traffic performance within the constraints of the project design. The geographic focus is the facility, and the temporal focus is day-to-day operations. As shown in table 3, the facility-specific MOEs are appropriate at this stage of the analysis, including vehicles per hour, travel times, delay, speed, stops per vehicle, queue storage ratios, and densities. Delay, speed, stops per vehicle, and queue storage are important in signal coordination analyses. Ramp delay, freeway mainline densities, and ramp queue storage are important for ramp metering analyses. Mean and 80 percent travel times are important for active transportation and demand management evaluations. Vehicles per hour processed by the facility are a measure of the facility’s productivity.

Table 3. Typical MOEs by analysis stage.

Dimension (Study focus)	Project Initiation (System, 20 years)	Project Clearance (Facility, 5 to 25 years)	PS&E (Design, < 5 years)	Construction (< 5 years)	Operations (Facility, day to day)
Utilization	VMT, PMT	VPH, D/C	V/C	V/C	VPH
Time	VHT, PHT	Mean, 80 percent	N/A	N/A	Mean, 80 percent
Delay	VHD, PHD	LOS	LOS	Delay/vehicle	Delay/vehicle
Speed	Mean	LOS, Mean	LOS	N/A	Mean
Stops	N/A	N/A	N/A	N/A	Stops/vehicle
Queue	N/A	N/A	95 percent QSR	95 percent QSR	95 percent QSR
Density	N/A	LOS	LOS	N/A	Mean
Collisions	Rate	Rate	N/A	N/A	N/A
Emissions	Tons	Tons	N/A	N/A	N/A

VPH = vehicles per hour, D/C = demand/capacity ratio, V/C = volume/capacity ratio, LOS = level of service, QSR = queue storage ratio, N/A = not applicable.

MOES BY TOOL CATEGORY

As shown in table 4, each traffic analysis tool category is designed to produce a particular set of MOEs suitable for the project development stage for which the tool is targeted. There is also significant overlap in the MOEs produced by the tool categories. Sketch planning and travel demand models are designed to produce system-level MOEs, although facility-specific MOEs can also be obtained from travel demand models. Deterministic HCM-based tools are designed to produce bottleneck-specific MOEs as well as facility-specific MOEs. Traffic control optimization tools generally focus on facility-specific MOEs. Traffic simulation models produce facility- and system-specific MOEs.

Table 4. MOEs by tool category.

Dimension (Tool focus)	Sketch Planning Tools (System)	Travel Demand Models (System)	Deterministic HCM-Based Tools (Facility, bottlenecks)	Optimization Tools (Facility)	Simulation Models (Facility)
Utilization	VMT, PMT	VMT, PMT, D/C	D/C	V/C	VMT, V/C
Time	VHT, PHT	VHT, PHT	Mean	Mean	VHT, Mean
Delay	VHD, PHD	VHD, PHD	Delay/vehicle, LOS	Delay/vehicle	VHD, Delay/vehicle
Speed	Mean	Mean	Mean, LOS	Mean	Mean
Stops	N/A	N/A	Stops/vehicle	Stops/vehicle	Stops/vehicle
Queue	N/A	N/A	95 percent QSR	95 percent QSR	95 percent QSR
Density	N/A	N/A	Mean, LOS	Mean	Mean
Collisions[a]	N/A	[a]	[a]	[a]	[a]
Emissions[a]	N/A	[a]	[a]	[a]	[a]

[a] Collisions and emissions are not usually directly predicted by the tool types described in this chart. The outputs of the traffic analysis tools usually must be input into the appropriate highway safety or emissions analysis software.
D/C = demand/capacity ratio, V/C = volume/capacity ratio, LOS = level of service, QSR = queue storage ratio,
N/A = not applicable.

Reconciling Tool Category MOEs

The key to reconciling MOEs between tools is to remember the focus and expertise of the tool (see figure 4). While a travel demand model can produce estimates of facility operation, that is not its focus nor its particular expertise. The HCM-type tools can also produce facility MOEs, but that is neither their focus nor their expertise. Simulation models and optimization models are the best source of facility-specific operations MOEs.

Reconciling MOEs between tools requires identifying the level of analysis being performed (bottleneck, facility, system) and which tools are best suited for that level of analysis. The MOEs produced by the less appropriate tool for the level of analysis should be considered less reliable than those produced by the appropriate tool.

Generally, it is best to report the MOEs produced by the more appropriate tool and discard the results produced by the less appropriate tool (see chapter 5 for more details). While it is certainly desirable to ensure that the results from both tools are similar, it is not worth the effort to make them identical. For example, the analyst might report the system-level demands and performance produced by the travel demand model but would report the operations results produced by the simulation model when reporting results for a specific facility. Both the demand and simulation models should agree that there is congestion on the facility, but they need not (and generally cannot be made to) agree precisely on the number of seconds of delay.

SELECTING MOES FOR MULTIPLE STAGES OF ANALYSIS

As previously explained, the objectives of the traffic analysis vary slightly by stage of project development. Thus, only rarely will the manager be able to select MOEs that are appropriate for every stage of the project development life cycle. Still, the manager can choose the appropriate MOEs for each stage of analysis, recognize when they will overlap and when they will supplement each other, and develop an analysis approach to address consistency issues as they arise.

For the early stages of the project development process (project initiation and project clearance), the manager should select MOEs that are appropriate for the system level of analysis. For the later stages of the project development process (project clearance, PS&E, construction, and operation), the manager should select MOEs appropriate for the facility level of analysis. Typical MOEs for each level of analysis are given in table 2.

Challenges of the Project Clearance Stage

The project clearance stage is unique in that both system-level and facility-specific MOEs are required. In addition, this stage requires extensive communication of results with decisionmakers and stakeholders; thus, the manager needs to identify indices for facilitating this communication.

The manager must employ a system analysis tool and a facility-specific tool to provide the broad-range MOEs required at the project clearance stage. The system-level tool can produce facility-specific results, but these will not be consistent with the facility-specific tool. These potentially inconsistent results must be translated into a consistent set of facility and system indices (such as level of service or demand/capacity ratio) for decisionmakers.

Reconciling MOEs at the Project Clearance Stage

In many cases, the facility will be a very small component of the system, and the facility performance results predicted by the system analysis tool will be similar to those produced by facility analysis tool. In this situation, the discrepancies are minor and can be ignored. The analyst simply reports the facility tool results for the facility and the system tool results for the system. The indices for each level of analysis are computed from the appropriate tool results.

Figure 8 shows one approach that can be used to generate consistent facility and system results when the facility is a significant component of the system performance or when discrepancies between the tools are great. In essence, the analyst uses the facility tool to generate and report the facility results. The system results are reported from the system-level tool but only after removing the facility-level results computed by the system-level tool and replacing them with the facility-level results produced by the facility tool. The system MOE indices are then computed from the modified system-level results.

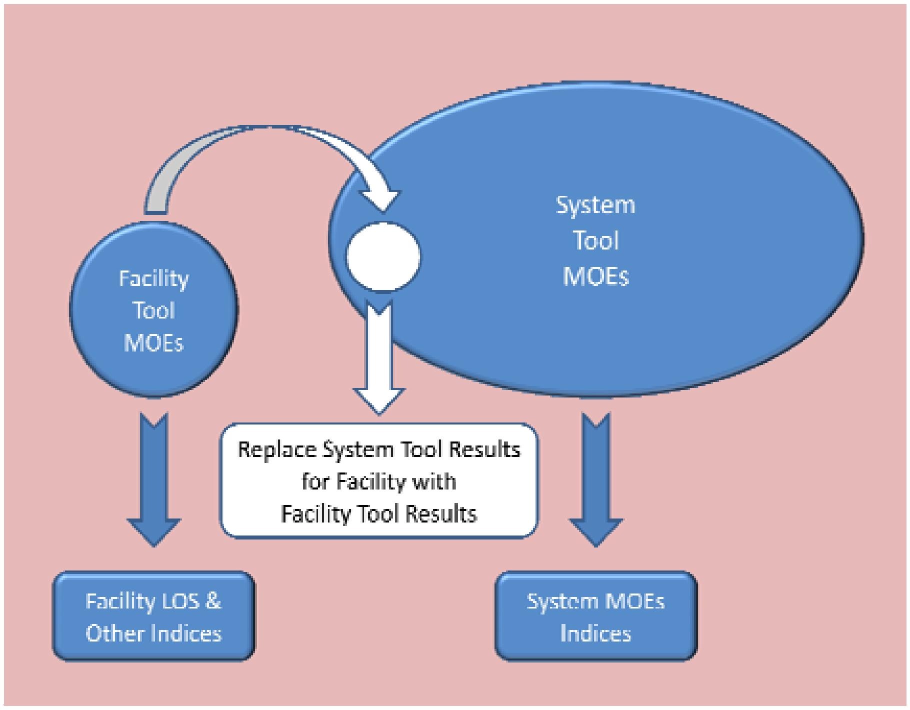


Figure 8. Chart. Reconciling facility MOEs, system MOEs, and indices.

The philosophy behind this approach is to use the most accurate tool to report the appropriate results, and together, the combined results will be more accurate for the system than the results of either tool alone.

CASE STUDY—MOE SELECTION AND RECONCILIATION ACROSS ANALYSIS STAGES

This hypothetical case study is a continuation of the HOV/HOT lanes case study described in the previous chapter. The project need and purpose have already been prepared. The manager is in the process of developing the overall PDAP and needs to identify the proposed MOEs for the various stages of the project and to develop an approach for dealing with potential inconsistencies in the MOEs that may arise during the stages of the analysis process. A preliminary set of MOEs was identified in the previous chapter. This discussion elaborates and refines them in light of the material in this chapter.

The initial project concept was to construct HOV lanes. A potential alternative to this project is to initially construct the HOV lanes and then convert them later to HOT lanes with associated ITS infrastructure improvements. Another potential alternative is to use the freeway median for a future extension of rail service either in addition to or in-lieu of the HOV lanes.

The project manager must develop two sets of MOEs. Both sets must be sufficient to distinguish the relative benefits of the proposed project and its potential alternatives. One set, the system-level MOEs will be for the early stages of project development and for the environmental analyses during the project clearance stage. The second set of MOEs will be for the project (facility)-specific analyses needed for project clearance, PS&E, and later stages of the project development process. Both sets are summarized in table 5 and discussed in more detail in the following sections.

Table 5. MOEs for HOV/HOT lanes case study.

Project Purpose	System-Level MOEs	Facility-Level MOEs
Reduce recurrent and non-recurrent congestion	VHD, average speed (mi/h)	Average delay/vehicle, average speed, level of service
Encourage HOV and transit use	Mode split HOV, transit	VPH HOVs, transit passengers
Support regional air quality attainment goals	Vehicle emissions	(Report at system level only)
Improve safety for motorists and agency maintenance workers	(Report at facility level only)	Collision rate per million VMT, collision rate during construction

VPH = vehicles per hour.

Selection of System-Level MOEs

The system-level MOEs are proposed for the project initiation stage and for the environmental analysis in the project clearance stage.

Measuring Reductions in Recurrent and Non-Recurrent Congestion

To measure the reduction in congestion (and to support the objective of encouraging HOV and transit use), the accumulated PHD is selected for the system-level MOE. Computation of system-level non-recurrent congestion is not practical with the available tools, so no system-level MOE for non-recurrent congestion is proposed. A useful indicator of the system benefits for decisionmakers is a change in system average speed, so this index is proposed as well. It is relatively easy to compute from typical system analysis tool outputs (the ratio of PMT/PHT).

Measuring Changes in HOV and Transit Use

At the system level, the daily percent of trips made by mode (the mode split) is a convenient MOE. It is commonly reported by most travel demand models. The home-based work mode split is a reasonable indicator of peak-period mode choice and (depending on the mode choice model used) is likely to be most sensitive to changes in congestion.

Measuring Support of Regional Air Quality Goals

VMT by average speed for the system can be input into an emissions model to determine the effects on regional emissions. The desired MOEs, however, are changes in the tons of regional emissions coming from vehicular sources.

Measuring Safety Improvements

Generally, collision rates and the specific facility characteristics affecting them are not well known at the system level. Consequently, the focus is on reporting safety results for the specific facility rather than for the system as a whole.

Selection of Facility-Level MOEs

Facility-level MOEs are used for the project clearance and later stages.

Measuring Reductions in Recurrent and Non-Recurrent Congestion

To measure reductions in congestion, the average delay per vehicle during the morning and evening peak hours on the facility is selected. To aid decisionmakers, the peak hours' level of service and average speed are also reported. Given the lack of tried and true tools for predicting the variability of travel time and the lack of agency experience with predicting reliability, the manager has elected not to report any specific travel time reliability measures.

Measuring Changes in HOV and Transit Use

At the facility level, mode choice can be reported but is more difficult to obtain from most travel demand models. A more convenient measure at the facility level is the number of HOV vehicles, their average occupancy, and the number bus passengers using the facility.

Measuring Support of Regional Air Quality Goals

Air quality is a regional measure. It is less meaningful at the facility level, unless carbon monoxide hotspots are a concern. If a facility-specific measure is desired, then the facility VMT by speed bin can be used by an emissions model to compute facility-specific emissions.

Measuring Safety Improvements

The facility-specific collision history and design features can be used to estimate collision rates during and after construction.

Reconciliation Across and Within Stages

As previously noted, the facility analysis tool produces facility-level MOEs and the system analysis tool produces system-level MOEs. In this case, the regional travel demand model is used to compute the system-level MOEs. The regional freeway system is so large compared to the project facility that discrepancies in the facility-level performance between the system and facility analysis tools are unlikely to significantly affect the system results. Consequently, the regional travel demand model results for PMT, PHT, and PHD are reported without modification.

Quality Assurance to Reconcile Tools

As part of the quality assurance program developed with the PDAP, the manager identifies a task to compare the predicted average speed for the length of the facility (within the project limits) from the regional travel demand model and from the facility HCM-style tool to verify that the predicted morning and evening peak performance is similar. (Prior to performing this check, the analyst should have verified that the HCM-type tool was given the correct peak-hour demands produced by the regional demand model.)

Should significant differences in predicted speeds be observed, the analyst would review the capacities and free-flow speeds coded into the two models and revise the demand model values to cause the demand model to better match the speeds predicted by the HCM-type tool. Since the two tool types use different methodologies to predict average speed, it is neither necessary nor desirable that the tools use identical free-flow speeds and capacities. The objective is to get the two tools to predict similar speeds for the selected analysis periods, forecast years, and project alternatives. However, should there still be wide discrepancies after this check, the analyst may consider developing a custom speed-flow equation for the subject facility to better reconcile the two models. A wholesale change of speed-flow equations for all facilities in the demand model should be avoided because it will change the original demand model validation. The revised speeds and capacities will cause the demand model to modify its predicted demands. These revised demands (if significantly different) should be entered into the HCM-type tool before a second comparison of the two models is performed.

CHAPTER 5. SELECTING CONSISTENT TOOLS, PARAMETERS, AND ASSUMPTIONS

This chapter provides guidance on the selection of traffic analysis tools, parameters, and assumptions to support consistent analysis throughout the project development process. This chapter builds on information about the strengths and weaknesses of each tool category that can be found in volume II of FHWA's *Traffic Analysis Tools Program*.[1] The general traffic analysis tool types and their salient strengths and weaknesses were covered in chapter 2. The MOEs output by each tool type were covered in chapter 4.

APPROPRIATE TOOL CATEGORIES BY STAGE OF PROJECT ANALYSIS

Traffic analysis tools have been developed and designed to address each stage of the project development life cycle. Some tools are useful for several stages while others are best limited to a single stage of the process (see figure 1).

As shown in figure 1, each tool category has both its feasible range of application and its optimal range of application within the project development stage. In many cases, multiple tool categories can be applied at the same project development stage. However, as discussed in chapter 4, it is best to use the tool best designed for each stage of the process at the appropriate stage.

Note that while the ranges of application overlap significantly, no single tool will carry the analyst through the entire project development process. Similarly, the analyst often has more than one tool type to choose from and may employ more than one tool type at each stage of the project development process.

Details of the tool categories and their uses are as follows:

- Sketch planning and travel demand models are used in the early stages of the analysis process. These tools are designed to work at very large geographic scales and forecast changes in demand over several decades.

    - Travel demand models are excellent tools for forecasting the long-term travel demand for a project and for determining the effects of the project on demand. Demand models are best at producing systemwide demands and performance. They are good at predicting facility-specific demands, but the analyst needs to check these demands for reasonableness (e.g., can the road system feeding the facility truly deliver the forecasted peak-hour demands?). Demand models are generally poor predictors of facility-specific performance results, although dynamic traffic assignment shows promise of improving this.

    - Sketch planning models are better at sensitivity tests of systemwide results. They do not produce facility-specific results and are generally poor predictors of facility-specific performance. Sketch planning tools are best for addressing demand forecasting issues that were not covered in the calibration of the original travel demand model.

- Deterministic HCM-based tools are best suited for the middle to end stages of the project development process. They are focused on bottleneck analyses but also have rudimentary facility analysis capabilities for freeways and urban streets.
    - HCM-based tools do not predict demand changes and, thus, need to be combined with a demand forecasting tool when dealing with long-term analyses and major projects likely to influence demand.
    - HCM-based tools, built off of extensive U.S. experience with highway operations, are necessarily limited to conventional improvement projects. High-tech state-of-the-art improvements, for which there is little experience in the United States, are not covered by HCM-based tools unless the software developer has extended the tool to cover situations not covered in the HCM.
- Traffic simulation tools work best with the greater project design information that is available at the project clearance stage.
    - Simulation models are ideal for bottleneck and facility analyses. They can also do system-level analyses, although the resource requirements put a practical limitation on the size of the system that can be simulated. Exceptionally large study areas are covered more cost-effectively with a travel demand model. Simulation models can also be useful tools for developing videos of traffic operations for communicating results to the general public. The manager should recognize that, if only the video is desired (no traffic MOEs), there may be alternative, less resource-intensive methods to generate videos of traffic conditions.
    - Practical resource requirements make simulation models poorly suited for evaluating numerous project alternatives at the early stages of project development. Simulation models are best applied after the alternatives have been reduced to a few options by the travel demand model or sketch planning analysis.
    - Resource requirements also make simulation models ill-suited for the PS&E and construction stages of project development. HCM-type techniques are generally more cost-effective at these stages.
    - The strength of simulation models is in their ability to deal with unconventional improvements for which satisfactory HCM-type techniques do not exist. The analyst can calibrate the best simulation models to reproduce almost any desired facility condition and driver behavior. This is both a strength and a weakness. Simulation models can give the analyst any answer desired. The trick is to ground the simulation analysis in some kind of observed behavior or known theory and not rely on the simulation model alone for the results.(1)
    - Simulation models are particularly strong at congestion modeling. However, the analyst will find that it is easy to overwhelm a simulation model with congestion. Once the congestion spills beyond the temporal and geographic boundaries of the simulation model, the accuracy of the results plummets. Relatively minor excess demands (5 to 10 percent above capacity) can rapidly spill over the boundaries of a simulation model.

- Traffic control optimization tools are designed for facility operation, the last stage of the project development process.
    - Optimization models are not necessary at earlier stages of the project development process and can be undesirable. One does not want to develop a project design that works satisfactorily with only one specific demand condition and signal control plan. Project development and design should build in the flexibility to operate several control plans so that the operating engineer can adapt the control plans to changing conditions in the field.

THE PROJECT NEED AND PROJECT INITIATION STAGES

At the project need and initiation stages, one is concerned with identifying system problems and possible solutions. A wide geographic coverage and the ability to easily test several widely varying alternative solutions are desirable.

Little is known about the project at this time, so it is not possible to model the facility operations in detail. Thus, the efforts necessary to conduct operations analyses using HCM analysis tools, optimization tools, and simulation models will not produce the desired precision of the results. The approximate representation of facility operations in the demand model is sufficient at this stage of the analysis to identify future problem spots and possible alternative solutions.

Study limits, forecast years, parameters, and assumptions should be kept conservative to reflect uncertainty at these early stages of project development.

Consistent Application of Sketch Planning and Travel Demand Models

The travel demand model is the best tool type to apply at these early stages of analysis. Sketch planning models may be used to supplement the demand model for conditions where the demand models lack the appropriate sensitivity (e.g., testing congestion pricing in a region where there are no existing toll facilities, and consequently, the demand model is not sensitive to tolls).

If the demand model already incorporates all of the desired sensitivities for evaluating project alternatives, then there is usually little or no need to employ sketch planning. Sketch planning should be used to introduce variable sensitivities not otherwise already incorporated in the demand model.

Coordinating Sketch Planning and Demand Model Outputs

Both sketch planning and travel demand models will generate systemwide MOEs such as VMT and VHT. However, the greater network detail of the typical demand model suggests that the travel demand model will produce more reliable estimates of systemwide performance. The sketch planning model results should be used to modify the demand model systemwide results, not replace them. For example, if the sketch planning model predicts that congestion pricing will change systemwide VMT by 5 percent, the demand model VMT should be changed by 5 percent to reflect the effects of congestion pricing.

Assumptions and Parameters for Early Stages of Project Development

Forecast Years

The forecast years should be conservatively far into the future to allow for slippages in the project delivery schedule. Thus, if the requirement during the project clearance stage is to evaluate project impacts for 20 years after project opening, the manager may elect to develop a 25- or 30-year forecast for the early stages of the project development process.

Study Limits

The temporal (time of day) and geographic limits of the study area should be oversized during the early stages of the project development process to ensure that the limits of the actual project impacts can be identified early in the process and result in significant savings in analysis effort during the later stages. A useful analysis at the project initiation stage is to identify the likely geographic and temporal bounds of the project impacts on traffic operations of nearby facilities. This will help scope the analysis during the project clearance stage.

Cumulative Improvement Assumptions

Generally, one should use the highway and transit network improvement assumptions incorporated in the agency's currently adopted long-range transportation plan. The manager will have to select between the agency's target or desired improvement program and its financially constrained improvement program. The selection will be based on the manager's experience as to decisionmakers' (those that will be involved in later stages of the process) perceptions of the relative acceptability of the different improvement programs for use in the environmental analyses.

Parameters

Capacities should be conservatively low during the early stages of project development. For example, level of service C capacities (approximately 80 percent of true capacity) may be used instead of HCM capacities in the planning analyses. This builds in a cushion for uncertainties in assumptions, project design, and operation at the early stages of project development.

THE PROJECT CLEARANCE STAGE

The project clearance stage is the most challenging stage for the manager to select and coordinate traffic analysis tools, MOEs, and assumptions. This is because this stage requires the most analysis and because there is a wide range of tools to accomplish the analysis.

The manager cannot avoid applying multiple tools at this stage. Project clearance requires detailed analyses of the proposed project demands and operations. Project clearance also requires a more far-ranging environmental analysis of the project and feasible alternatives. The environmental analysis requires a systemwide evaluation of the project effects. Thus, multiple tools are required, and the manager and analyst must take steps to ensure that the tools work together consistently to produce valid results.

Management of Consistency Within the Project Clearance Stage

The two keys to managing consistency in the project clearance stage are as follows:

- Use each tool only for the analyses that it is best at.
- Scope the study broadly and conservatively in the early stages of the analysis when project details are still in flux, and then gradually narrow down the analysis scope to more precisely reflect project details in the later stages of the analysis.

Using each tool only for the analyses it is best at means, for example, not using a travel demand model to report specific facility operating results when a similar analysis is available from a superior operations analysis tool such as the HCM, optimization, or simulation models.

Scoping broadly and conservatively means that, early in the project clearance stage, the manager and analyst should adopt relatively large geographic and temporal boundaries for the analysis until the alternatives and the project impacts are better defined and the scope of analysis can be narrowed.

Analysis Requirements During Project Clearance Stage

The analysis requirements of the project clearance stage include demand forecasting and performance analysis. Both of these analyses need to be done at the systemwide and facility-specific levels.

Demand Analysis Tools for Project Clearance

The long-term systemwide and facility-specific forecasting of demands are best done using a travel demand forecasting model. This is the only available tool type for these analyses. Sketch planning tools generally do not provide sufficient details for the project clearance stage. If sketch planning models are used, it should be to fill one or more gaps in the sensitivities of the travel demand forecasting model to features of the project or its alternatives.

Managing Consistency During the Demand Analysis

Caution should be used when using demand models to forecast specific facility conditions in the short term (under 5 years). Residual calibration error for the facility may be greater than the forecasted growth for the facility. In such cases, the raw model forecasts should be adjusted for residual validation year error for the subject facility. This will ensure that the short-term model forecasts for the facility are consistent with the existing year counts.

In all cases, when using a demand model to forecast facility-specific demands, the manager and analyst should employ the following steps to ensure consistency:

1. Verify that the facility is correctly coded in the demand model for both existing and future conditions.

    a. Check connectivity to the adjacent road system, segment lengths, lanes, free-flow speeds, capacities, and volume-delay functions.

    b. Verify capacities against HCM or field observations, if available.

2. Verify that the demand model-predicted facility performance for existing conditions is similar to that observed in the field or estimated using an HCM-type tool. If the demand model-predicted average speed of traffic on the facility is greatly different from the observed, the analyst should return to the previous step and determine if additional adjustments are needed to the free-flow speed, capacities, and volume-delay functions used for the facility.

    a. Keep adjustments facility-specific. Global changes to systemwide speeds, capacities, or volume-delay functions will require revisiting the overall demand model calibration and validation.

    b. Consider employing dynamic traffic assignment to improve facility performance predictions (see discussion in following sections).

3. Adjust demand model forecasts for differences between facility counts and count year model estimates. These become the facility segment-specific volume corrections that should be added to the model forecasts for the facility. Alternatively, the analyst may use the model to develop growth factors that are applied to existing counts. Either way, the analyst should use and report the adjusted forecast results rather than the raw model forecasts for the facility.

4. Validate that the forecasted demand model operations for the facility are similar to those predicted by an HCM-type tool (or optimization tool or simulation model) for the facility. If the overall average speed for the facility is within tolerances for both the demand model and the HCM-type (or other operations) tool, then the analyst can be confident that the demand model is predicting approximately the right demands for the facility. Greater differences should be corrected by examining and adjusting the demand model capacities, free-flow speeds, and volume-delay functions for the facility. See *Travel Model Validation and Reasonableness Checking*.(6)

5. When using a demand model to determine the geographic scope of project demand effects, be sure to use a sufficient number of equilibrium iterations and a tight enough equilibrium closure criterion to ensure that forecasted project/no-project differences in link volumes are truly due to project differences and not to differences in how close the model got to equilibrium each time. Volume effects that are not contiguous (a minor volume change in a subarea with no other volume changes) should be considered equilibrium closure inaccuracies rather than project effects.

Emerging Option—DTA

DTA is the loading of traffic onto a highway network in a sequential series of time slices within the overall analysis period (usually the peak period) using a procedure called dynamic user equilibrium (DUE). DUE is the equilibration of traffic based on experienced travel times.(7) As agencies and their personnel build up experience with DTA, the manager may consider employing this tool to improve the accuracy of the facility performance predicted by the demand model. If the agency has little experience applying DTA, the manager should be cautious about ensuring sufficient contingencies are built into the budget and schedule to overcome unexpected difficulties that can arise when using a new tool for project delivery purposes.

If DTA has not been previously employed with the demand model, the manager should realize that a complete recalibration and revalidation of the demand model will be necessary. DTA will throw off the previous calibration and validation of the demand model.

Performance Analysis—Systemwide

System performance analysis (e.g., VHT, VHD, etc.) can be done using either travel demand models or simulation models. HCM-type tools are not currently capable of system performance analysis.

Using an existing travel demand model will be much less resource-intensive than developing a simulation model from scratch. However, the demand model will produce less precise performance results. Overall system performance may be about right in the demand model, but the specific links and facilities that the demand model predicts are congested may not be right.

Exceptionally large study areas are most cost-effectively modeled in travel demand models. Practical resource considerations limit the attractiveness of using simulation models for study areas over 20 mi in length. Simulation can be and has been done for larger areas, but the resource requirements (staff, data, and time) are high.

Improving the System Performance Accuracy of Demand Models

Concerns about the accuracy of the systemwide performance predictions from demand models can be controlled and managed as follows:

- Verifying that the demand model was recently calibrated and validated. The validation has preferably been done in the last 5 years and must have been done in the last 10 years.
- Verifying that the demand model uses capacities consistent with the HCM.
- Verifying the accuracy of the highway and transit network geometry in the vicinity of the proposed project (facility type, lengths, connectivity, free-flow speeds, lanes, capacities, and volume-delay functions) for both existing and future conditions.

Emerging Option—Adding DTA

DTA shows promise for improving the system performance predictions of travel demand models without incurring the great expense of creating a simulation model. DTA may also facilitate multiresolution modeling by achieving better consistency between travel demand models and HCM/simulation models. However, if an agency has little or no experience with DTA, it should be treated as a research effort (with the inherent schedule and budget risks associated with research) until the agency acquires more experience with it.

Use of Simulation Models for Systemwide Performance Analysis

For moderate- to small-sized study areas, study resources may permit the development and use of a simulation model to predict system performance in lieu of the travel demand model. A simulation model will provide much superior system performance results for existing and near-term conditions as long as congestion can be kept within the geographic and temporal bounds of the simulation model. Once these bounds are exceeded, the simulation model may provide system performance results that are inferior to that of the demand model. The simulation model may still more accurately predict the performance of specific segments within the facility, but its estimates of systemwide delay will be thrown off by congestion spilling over the borders of the model.

If a simulation model is to be used to produce system performance results, a demand model will still be needed to produce the demand forecasts. The manager and analyst must ensure that there is approximate consistency between the system performance information used by the demand model to predict demands and the system performance predicted by the simulation model for those predicted demands.

It is suggested that the predicted systemwide average speeds of the two model types (demand and simulation) be compared to ensure that they are approximately consistent.(6) This check should be made for both existing and future conditions. The analyst should not force the demand model to predict the same locations and amounts of congestion as the simulation model on a link-by-link basis (although this kind of examination may be useful in understanding sources of discrepancies and fixing them). The goal is to ensure the demands produced by the demand model are roughly in agreement with the performance predicted by the simulation model.

Performance Analysis—Facility-Specific

The analysis of facility-specific performance for future conditions is best done using HCM-type tools, control optimization tools, and simulation models. Control optimization tools have built-in simulators that are excellent for forecasting facility performance under prevailing control conditions. HCM-type tools are excellent for sizing a facility to avoid bottlenecks. Simulation models are best for situations where a simpler HCM-type or optimization tool cannot produce the needed performance accuracy. Simulation models are also better than HCM-type tools for evaluating oversaturated conditions, in which demand is greater than capacity.

Demand models are generally not satisfactory for evaluating facility-specific performance. The peak spreading effects of upstream bottlenecks on downstream volumes are not treated in conventional travel demand models. Congested speeds may be shown for the wrong segments of the facility. Demand models typically show congestion occurring on the bottleneck segment, rather than upstream of the bottleneck. DTA can improve this capability, but the manager should ensure that his or her agency has or can obtain the necessary expertise before employing it in project development work.

The manager's first choice for analysis tools at the individual facility level should be the optimization tools. If an optimization tool is available for the selected facility type, then the optimization tool combines the relative data efficiency of HCM-type analyses with the ability to optimize control settings during the operation of the facility.

Should a suitable optimization tool not be available, the next best choice is an HCM-type tool. This type of tool has a relatively high data efficiency (least data required to produce suitably reliable performance results).

Should the project being evaluated involve sophisticated operations management features not incorporated in the HCM methods or should it involve dealing with the management of congestion spillovers within the facility, then the manager should use a simulation model. Macroscopic or mesoscopic simulation models are more data-efficient then microscopic simulation models. However, if the HCM-type tools are unable to deal accurately with the situation, it will probably be a challenge for the macroscopic models and may be a challenge for the mesoscopic simulation models.

At the current state of the practice, the manager and analyst are usually confronted with developing a microsimulation model from scratch. This is often as resource-intensive as creating a demand model from scratch. Should a previously coded and calibrated DTA model be available for the project site, then some data-collection effort for the microsimulation model may be avoided. This has been the basis of the discussion regarding the selection of analysis models; however, should one be fortunate enough to already have a calibrated simulation model available for the facility, the data requirements implicit in the previous discussions are avoided and the use of a previously calibrated microsimulation model can be more cost-effective than even HCM analyses.

Managing Consistency at the Facility-Specific Level

Whichever tool is selected to perform the facility-specific performance analysis, that tool should be used to report all facility performance results. For example, if CORSIM was used to generate the facility travel times, it should also be used to identify bottlenecks, queues, flows, average speeds, and delays for the facility. Unless the manager has some doubts about the tool, there is little reason to use multiple tools to do the same thing. The best way to avoid consistency problems is to avoid unnecessarily introducing inconsistency.

The facility-specific results from travel demand models should be checked for general consistency with the selected traffic operations analysis tool (HCM, optimization, simulation), as previously explained. However, the facility-specific results from demand models should generally not be reported. DTA may eventually overcome this weakness of travel demand models for predicting facility segment-specific performance.

Managing Assumptions and Parameters During the Project Clearance Stage

Forecast Years

The forecast years need not be as far into the future as they were in the earlier project delivery stages; however, significant delivery schedule slippages can still occur even within the project clearance stage. Consequently, it pays to be a bit conservative to allow for possible slippages in the project delivery schedule. Thus, if the requirement during the project clearance stage is to evaluate project impacts for 20 years after project opening, the manager may elect to develop both a 20-year forecast and a 25-year forecast just in case there are unexpected delays and slippages during the environmental review process.

Study Limits

The temporal (time of day) and geographic limits of the study area should be better bounded at this stage to avoid over-expenditure of resources during the project clearance process. The manager and analyst may elect to slightly oversize the limits so decisionmakers can see that all relevant impacts have been covered. Alternatively, the manager may point to earlier analyses that bounded the impacts of the project during the project initiation stage.

Cumulative Improvement Assumptions

The manager should recognize that, at the project clearance stage, decisionmakers and stakeholders will have a significant influence on the cumulative improvement assumptions to be made for the project analysis. An early meeting with these participants to pin down and document assumptions may be very effective. If such a meeting cannot be practically scheduled before the analysis must be performed, the manager may attempt to bracket the potential input from decisionmakers by selecting a few sets of assumptions and splitting them into high-, medium-, and low-level scenarios. The analysis is then repeated for each scenario of assumptions.

Parameters

Capacities used during the early and later steps of the project clearance stage should generally be as consistent as possible, recognizing that they will invariably change as the project design and its alternatives are refined. If the analyst is confronted with a great deal of uncertainty regarding the project design at the start of the project clearance stage, he or she might resort to high-, medium-, and low-level scenarios for the project design and then discard the irrelevant scenarios as the project is better defined.

THE PS&E, CONSTRUCTION, AND OPERATION STAGES

The objectives during PS&E, construction, and operation are the design, construction, and operation of the facility. During these stages, the project specifics are defined, built, and operated. The focus is on specific bottlenecks in the facility and the overall facility operation. At these stages of project development, HCM-type tools, control optimization tools, and simulation models are the best available tools for assessing facility and bottleneck performance.

The HCM-type tools are best for sizing and designing facilities to avoid congestion. They are quick to apply and require comparatively little data. Calibration data is generally not required. The rapid-response capabilities of HCM-type tools make them useful for design and construction. However, their lack of optimization capabilities makes HCM-type tools less useful for operating a facility.

Optimization tools generally automate the evaluation of multiple bottlenecks within a facility better than the HCM. However, most optimization tools, being based on HCM methods, suffer the same weaknesses as the HCM when dealing with the spillover effects of congestion on facility operation. Optimization tools are designed for operating the facility.

Simulation models should be used where constraints do not permit sizing the facility to avoid congestion and it is necessary to manage the spillover effects of congestion within the facility. Simulation models are the most resource-intensive of the three tool types discussed. They must always be calibrated. The resource and time requirements generally make the creation of new simulation models from scratch of less use during construction of the facility. Their lack of optimization capabilities generally reduces the value of simulation models for facility operation.

Managing Consistency in the Later Stages of Project Development

During the later stages of project development, the greatest concern is delivering a project that will be successful in its real-world setting. Consistency in these later stages is a good first-order quality control check on the analysis. However, being right is more important than consistency in these later stages of project development.

CASE STUDY—TOOL, PARAMETER, AND ASSUMPTION SELECTION

This case study is a continuation of HOV/HOT lanes project described in previous chapters. The manager is in the process of developing the overall PDAP and has identified the desired MOEs for the various stages of the project. Now, the manager must identify the proposed analysis tools for each stage and the process that will be used to ensure consistency among the various tools. Table 6 provides an overview of the selected tools by stage of project development.

Table 6. Tools selected for HOV/HOT lanes case study.

Project Development Stage	MOEs	Selected Tool	Comments
Project need/initiation	System and facility MOEs	Travel demand model supplemented with sketch planning model	Sketch planning model used to help demand model estimate demand effects of tolls for HOT lane alternative. Facility results used to help scope project, its alternatives, and likely scope of project effects on facility demands. Numerical performance results not considered definitive for a specific facility.
Project clearance	System MOEs	Travel demand model supplemented with sketch planning model	Models used to estimate system and facility demands. Models used to estimate performance only for system MOEs.
	Facility MOEs	HCM (or optimization model) supplemented with microsimulation	The selected HCM (or optimization) tool will predict mixed-flow lane operations but is unable to deal with proposed HOT lane access options. Microsimulation will be used to evaluate a few prototypical access options, and the results will supplement the HCM results.
PS&E, construction, and operation	System MOEs	Not applicable	System effects were dealt with in previous stage.
	Facility MOEs	HCM or optimization tools	Simulation models would be used only if available from earlier stage.

Notes: The selected system MOEs are VHD, average speed, mode split, and VMT by speed bin. The selected facility MOEs are delay/vehicle, speed, level of service, HOV volumes, transit patronage, collision rate during construction, and collision rate after open.

Selection of Tools, Parameters, Assumptions for Early Stages

During the project needs and initiation stages of project development, the focus is necessarily on a large possible project impact area and a wide-ranging set of alternatives. In these early stages of the HOV/HOT lanes project development, a previously calibrated and validated regional or subregional travel demand is the best tool for analyses.

Selection of Primary Analysis Tool

In this case study, two previously calibrated demand models were considered by the manager: the regional travel demand model and a subregional, countywide model. Both were conventional four-step models with trip generation, distribution, mode choice, and traffic/transit assignment capabilities. The county model was designed to be consistent with the regional model with additional network and land use detail within the county.

Interregional trips were a significant portion of the traffic on the freeway in this case study; consequently, both the regional and county models were assessed for the abilities to forecast interregional trips. The county model employed a super-zone system to model the adjacent county (which falls outside of the metropolitan region), and the regional model employed manually derived fixed external trip forecasts.

Because of the superior network and land use detail in the vicinity of the proposed HOV/HOT lane project and the superior external trip forecasting capability, the county model should be selected as the demand model to be used throughout the project development process.

Selection of Supporting Tool

The demand model should be satisfactory for predicting the requisite system MOEs for the early stages of project development: VHD, average speed, and mode split. However, it is not be sufficient to predict the effects of the project alternative of installing an HOT lane instead of an HOV lane.

In this case study, the county model, like the regional model, has the capability to test the effects of tolls on mode choice but lacks the ability to test the effects of tolls on route choice (facility choice). Consequently, a sketch planning model is needed to identify how many of the county model-predicted single-occupancy vehicles (SOVs) on the freeway will be willing to pay a toll to use the HOT lanes. The demand model is used to predict how many SOVs and HOVs will use the total freeway facility. The sketch planning model will be used to split the SOVs using the freeway into toll-paying and non-toll-paying SOVs.

The manager would investigate the available toll analysis sketch planning tools used in previous HOT lane studies. In this case study, the toll elasticities in the regional model would be considered sufficient to construct a simple spreadsheet post-processor. For each cell in the freeway facility origin-destination table, the spreadsheet reads the relative travel times in the mixed-flow lanes and the HOT lanes, applies the toll elasticities, and predicts the percent of SOVs that will pay the toll for different toll schedules.

Selection of Assumptions

Toll schedule: At this early stage in project development, the toll schedule would not be known, so the manager and analyst assume that the toll schedule would be set to keep the total volume in the HOT lane at or near a target of 1,650 vehicles per hour (a target set separately by the agency operating the HOT lanes). The sketch planning tool, the SOV toll processor, would then be used during the project clearance stage to compute the likely toll schedule required to approximately achieve that target.

HOV operating hours and occupancy: Ordinarily, the manager would be able to assume the standard agency policy for HOV operating hours and occupancy requirements. However, the HOT lane alternative introduces more complexity. Thus, the manager should be prepared to scope the study to address multiple HOV occupancy requirements and the possibility of extended or all-day operation.

Forecast years: The manager would look at the available forecast year data sets in the selected travel demand model and pick the forecast year that falls closest to one of the available model data sets. If necessary, the manager may scope for linear extrapolation of the model forecast data set to a later year to provide sufficient cushion for slippages in the project delivery schedule. In this case, a 2030 forecast year was available, but the manager conservatively plans to extend this forecast model dataset to 2035 to allow for delays during the project delivery process.

Assumed cumulative projects: The manager would examine the regional transportation plan and, thinking ahead, select the set of projects that would best meet the needs of the project clearance stage. Since the environmental analysis that is performed during project clearance generally conservatively assumes a financially constrained set of cumulative improvement projects, that is the set the manager would select from the regional transportation plan for this analysis. Ideally, this decision would be made with input from the decisionmakers and stakeholders; however, their input will not be secured until the project clearance stage. So, the manager must make an educated guess based on environmental analyses previously conducted by the agency.

Study limits: The initial study limits are set by the selected travel demand model, the region. The study limits can be refined for later stages of analysis based on the results of these initial studies. The large study area is guaranteed to trap all significant project impacts; however, the manager and analyst should be prepared to deal with a dilution of project effects when using a large study area. If this is an issue, the manager may elect to identify a secondary, focused study area for accumulating system MOEs. This will avoid diluting the project effects. The regional study area is retained to ensure that all significant project effects are trapped in the model, while the secondary, focused subarea is used to accumulate system MOEs that better convey the effects of the project on facilities in the area.

Use of Facility Performance Results

The results of the earlier stages of project analysis will be used to help scope the project, its alternatives, and likely the project effects on facility demands. The numerical performance results for the project facility, which are produced in these early analysis stages, will be replaced later by more definitive results.

Selection of Tools, Parameters, Assumptions for Project Clearance Stage

During the project clearance stage of project development, the focus is on both project detail and on a wider project impact area. At this stage of the HOV/HOT lanes project development, a combination of system- and facility-specific tools are required to support the analysis.

Selection of Primary and Supporting Analysis Tools—System MOEs

To forecast systemwide and facility-specific demands, the same combination of travel demand and sketch planning models are recommended as identified for the project initiation stage. This combination of demand and sketch planning models should also be used to generate system MOEs.

Selection of Primary and Supporting Analysis Tools—Facility MOEs

To evaluate facility-specific operations, the agency had an in-house tool for evaluating freeway operations. In this instance, the tool was the University of California's FREQ model. The HCM 2010 freeway analysis tool, FREEVAL, could also have been selected; however, with FREEVAL, additional simulation modeling would have been needed to address ramp metering and HOV lane options as well as HOT lane access options. The HCM-based tool used is able to model ramp metering and HOV lanes but was not developed to evaluate the controlled access features of HOT lanes. The manager therefore elected to use a simulation model to test various designs for providing access to the HOT lanes. The simulation targeted answers to HOT lane operations questions that could not be answered with the HCM-based tool.

Since the project will increase the throughput capacity of the freeway facility, it is likely to offload the adjacent surface street system. The demand model may be sufficient to identify the general direction and magnitude of the demand and performance changes for the surface streets.

If the project and one or more of its alternatives were to include a ramp metering component (or other features) that might reduce the throughput capacity of the freeway, then there may be concerns about the impacts on surface streets in the area. Under such a condition, a separate HCM-type tool would be selected to generate performance measures for the adjacent surface street system likely to be impacted by the project. The HCM-produced performance measures for these streets would supersede the performance outputs coming from the demand model. If significant and complex diversion effects are expected, the manager should select a tool that can integrate arterial and freeway performance with a diversion (route choice) prediction capability, such as is provided by many microscopic and mesoscopic simulation models. The ability of the simulation model to accurately represent intersection signal controls and the route choice algorithm employed in the model should be investigated by the manager to ensure that the model will perform as expected.

The project manager would develop an analysis protocol that addresses how freeway demands are handed off to the surface street HCM tool and how surface street demands are handed off to the freeway HCM tool.

The manager should provide for one or more checks to ensure that the freeway and surface street HCM models are working with consistent volumes at their interface in the future forecast years. For example, if the demand model says the demand is X for the off-ramp but the HCM tool says only Y can actually arrive there, the analyst will need to determine if the difference adversely affects the conclusions of the overall analysis. If so, then a simulation model integrating the freeway and surface street system would be required in lieu of the HCM tools.

A simulation model of the corridor would solve the freeway and surface street interface problem by integrating both facility types into a single model. However, creating a simulation model from scratch puts a significant strain on project analysis resources.

Scoping for Facility Closures and Construction Detours

If facility closures are contemplated for the construction phase of the project, it may be highly desirable for the manager to incorporate an HCM-type tool (or optimization or simulation) in the project clearance scope for the nearby off-facility street system to facilitate construction detour planning. Construction detour planning is generally beyond the capabilities of conventional travel demand models.

Selection of Assumptions

Toll schedule, HOV occupancy, hours of operation: At the project clearance stage, the toll schedule would still not be known. However, the environmental analysis will need to address the potential range of tolls that might be used. The manager and analyst would address this issue by positing several toll schedules, HOV occupancy requirements, and hours of operations. Schedules might be created to maximize person throughput, maximize vehicle throughput (subject to not exceeding the agency's target operating capacity), or to maximize revenues.

Forecast years: See the previous discussion on forecast years for the earlier stages of the project development.

Assumed cumulative projects: The manager would examine the regional long-range transportation plan and select the set of projects that would best meet the needs of the environmental analysis. If input from decisionmakers and stakeholders on these assumptions cannot be obtained early enough in the process, the manager and analyst may try to cover the possibilities through a series of future improvement scenarios. Scenarios cover more bases for the manager, but this advantage comes at the expense of greatly increasing the resources required to complete the analysis.

Study limits: See the previous discussion on study limits for the earlier stages of the project development.

Managing Consistency Between Analysis Tools

The analysis plan for the project clearance stage would incorporate the following techniques to manage consistency across the analysis tools:

- Demand model base year and future year network coding for the subarea in the vicinity of the proposed project and its alternatives would be error checked against base year observations and future year plans for network improvements.

- Demand model base year volumes would be validated against base year traffic counts. Model parameters and network coding would be modified to improve the validation. The objective would be to make as few changes as possible to the previously calibrated model while achieving the validation targets for the facility and its vicinity.

- The demand model-predicted base year performance (average speed) for the project facility would be compared to base year observations and the model adjusted to improve the match.

- For the future year no-project baseline forecasts, the predicted average facility performance (average speed) produced by the demand model would be compared to facility average speed predicted by the selected facility operations analysis tool, in this case the HCM-type tool. The demand model speed-flow equation (volume-delay function) would be adjusted for the facility, if necessary, to achieve a more consistent match between the demand model and HCM tool.

- Conflicts between simulation results and the HCM tool would be minimized by using simulation to provide supplemental capacity and performance effects for HOT lane access designs not currently incorporated in the HCM tool. The HCM tool inputs (capacity, etc.) for each HOT lane access point would be modified based on the simulation results.

- The freeway HCM tool would be used to generate freeway MOEs. The surface street HCM tool would be used to generate surface street MOEs. The demand model would indicate the demands for each HCM model.

- The demand model would be used to generate system MOEs for the portion of the entire model network that falls within the significant influence area of the proposed project and its alternatives. The demand model-produced MOEs for the project facility and adjacent streets would be replaced with the HCM tool-predicted project facility MOEs, thus avoiding a potential source of inconsistency (discrepancies between demand model and HCM tool estimates of project facility performance).

Selection of Tools, Parameters, Assumptions for Later Stages

During PS&E, construction, and operations, the focus is on the facility. System analyses are no longer required (having been dealt with exhaustively in the project clearance stage). The appropriate analysis tools for these later stages of project development are consequently HCM-type tools, optimization tools, and simulation models.

There is much value in continuing with the tools developed and validated for the project clearance stage. In this case, since an HCM-type tool was selected for project clearance, the same tool would be useful for any lingering design questions not previously addressed.

A simulation model could also be used in the later stages, if it was previously created for the project clearance stage.

At these later stages, consistency is a good quality control check; however, getting the correct answers quickly to design, construction, and operation questions is most important.

In scoping the traffic analysis for the PS&E and construction stages, the manager should recognize that construction detours for overnight facility closures may require significant off-facility analysis of the proposed detour routes. Even if an off-facility HCM-type tool was not required during the project clearance stage, it may be required during the PS&E stage.

CHAPTER 6. UTILIZING OUTPUTS FROM DIFFERENT TOOLS

This chapter describes how the outputs from different analysis tool types can be combined into an overall presentation of technical analysis results.

PRINCIPLES FOR MANAGING CONSISTENCY IN OUTPUTS

The first principle that the analyst should observe is that any technical answer is the analyst's responsibility. The analyst owns the results, not the tool. The simulation model cannot say the average speed will be 35.4 mi/h. The analyst says so after extensively reviewing the results and comparing them to industry norms. It is the analyst that produces the answers, not the tool.

The second principle is that when confronted with differing results from two different tools, the analyst should place greater confidence in the results produced by the better tool (see chapter 5).

The third principle is that it is the job of the analyst to understand the capabilities and limitations for each tool and to treat results with caution in situations that fall on the fringes of the tool's application range.

Finally, inconsistencies cannot be eliminated; they must be managed and controlled. The natural flaws in any tool that attempts to approximate the real world ensures that no two tools will get precisely the same answer. The job of the analyst is to weigh the differing results and to deliver the best answer. The best answer is not necessarily either model A or model B; it could be something in between. If the manager and the analyst have been successful in ensuring consistency throughout the analysis process, then both models should be pointing to the same overall conclusions, only differing in minor numerical details.

RECONCILING AND UTILIZING OUTPUTS FROM DIFFERENT TOOLS

As described in the previous chapters, when two tools produce performance results for the same situation, if there is a clearly superior tool, then the analyst should rely on the results from the superior tool and neglect the results from the inferior tool.

The most common situation occurs when the analyst is using a demand model to develop forecasts and an HCM-type tool (or optimization tool or simulation model) to produce MOEs. In order to predict demand, the demand model needs to forecast performance, but it uses a very approximate method to predict facility performance. Obviously, the analyst will not report the demand model MOEs related to facility performance. However, since facility performance is an important determinant of demand, it is important that the demand model be working with estimates of facility performance that are similar to those estimated by the HCM-type tool. Steps to achieve this consistency were addressed in the previous chapters.

However, there are situations where the analyst will apply two tools in parallel, because neither tool provides the complete solution to a complex problem. An example is the application of both a simulation model and an HCM-type tool within the same study. This may occur because the analyst wishes to report level-of-service results for complex situations that can best be modeled in a simulation model. The analyst is trying to overcome the difficulty of communicating simulation results by using HCM levels of service, which decisionmakers are more familiar with.

To reconcile the MOEs produced by a simulation model and an HCM type tool, the analyst is faced with the following challenges:

- Differences in temporal periods covered by the two tools (HCM is peak 15-min period within peak hour; simulation models usually cover a much longer period).

- Definitional differences in the MOEs (delay, average speed, queue).

- Measurement differences for the MOEs.

For advice on the sources of inconsistency and methods for reducing them between simulation models and the HCM, the analyst should consult chapters 6, 7, and 24 of the 2010 HCM.(8) The report for National Cooperative Highway Research Program (NCHRP) project 3-85, *Guidance for the Use of Alternative Traffic Analysis Tools in Highway Capacity Analyses*, is also a good reference.(9) Generally, the analyst should be prepared to do significant data processing to convert simulation outputs into something that could be reported as HCM level of service. Even so, the analyst should be prepared to accept that there could still be residual inconsistencies because of fundamental differences in how the two tools model vehicle trajectories in the traffic stream.

EXPLAINING INCONSISTENT RESULTS

Despite the best efforts of the analyst and manager, there could still be apparent and real inconsistencies between tools, between different analysis stages, and among different agencies. In almost all cases, the best approach is to spot these inconsistencies before others do. That way, the manager and analyst can either modify their own analysis or prepare explanations for why the new study is better than the previous study.

There are differing sources of potential inconsistencies and differing ways to deal with them. Three potential sources of inconsistencies are as follows:

- Work the primary agency has performed.

- Work done by another agency in the same study area.

- Observations made by others, including decisionmakers and the public.

Work the Primary Agency Has Performed

It is, of course, best to control and manage any inconsistencies between analysis results and any work previously performed by an agency. A proactive approach to consistency in the scoping phase is the best deterrent to this issue (see chapter 2). However, there may be times where analysis results are inconsistent with prior analyses performed by the agency because the new results are better. This can occur for a number of reasons, including the following:

- Refined analysis tool type employed. The new analysis may have been conducted using a more detailed class of analysis tools, such as microsimulation, while the previous analysis was performed using deterministic methods. Or perhaps the opposite is true if a tool was used that is less sophisticated but more expedient to meet the needs of the current analysis.

- Revised input parameters. The previous analysis may have been conducted using input data that has subsequently changed by the time of the new analysis. Examples could include revised projections of socioeconomic data that serve as inputs to the travel demand model, changes to capital improvement projects expected to be included in baseline conditions, or extended future forecast years for the analysis.

- Updated software tools used within tool class. The new analysis may have been conducted using a more recent version of the analysis software than was employed in the previous analysis, reflecting refinements to the calculation procedures.

The appropriate response to inconsistencies between earlier and later studies performed by an agency is to proactively identify the inconsistencies before they are spotted by others and explain the evolutionary nature of the agency's traffic analysis. As better information and better tools become available, the agency naturally wants to present the best possible information to decisionmakers, stakeholders, and the general public.

Work Done by Another Agency in the Same Study Area

The analyst and manager should make themselves aware of prior and ongoing work by other public agencies and consultants in the area and proactively identify potential inconsistencies between the work of others and their own work. The key is to identify potential inconsistencies before the problem is brought to the agency's attention by others. The manager and the analyst can then determine whether to modify their own analysis or to prepare a rationale for the differences. It is not critical to be consistent if good reasons can be found for differences. Possible reasons include the following:

- Different starting points. The analysis results may vary from another jurisdiction's due to the use of different assumptions at various points in the traffic analysis sequence. This may include the use of different jurisdiction-specific methodologies or different travel demand models for forecasting traffic volumes.

- Different levels of detail depending on study purpose. The analysis may reflect a more detailed approach than was previously conducted, which may be related to the differing purposes of your study compared to one prepared by another agency.

- Reasons listed in previous section. Potentially, the same reasons that may lead to inconsistency with work an agency has conducted may also be valid for inconsistency between one analysis and that of another jurisdiction. These include the usage of revised analysis tool types, the use of revised input parameters, and the use of updated software tools within the same tool class.

Again, the goal is to highlight the differences and point to why the new analysis reflects the correct approach for the current study.

Observations Made by Decisionmakers or General Public

Commonly, someone's personal observations of the traffic characteristics of the study area, be it a decisionmaker or member of the general public, is compared and contrasted with analysis results and used to identify inconsistencies. These inconsistencies may only be perceived rather than actual, as they are based on limited observation.

The best advice is to make field visits to the study area during the time periods that correspond with those of the traffic analysis. This will inform work regarding validation of existing conditions analysis as well as allow confident professional interpretation of field conditions when responding to the observations made by others, boosting credibility along the way.

For any of these cases, anticipate the potential for inconsistency and prepare communication accordingly. This can be accomplished by summarizing and explaining the consistency issues, as well as anticipating questions and answering them in reports or presentations.

CASE STUDY—UTILIZATION OF OUTPUTS FROM DIFFERENT TOOLS

This hypothetical case study is a continuation of the HOV/HOT lanes project case study described previously. The manager is in the process of developing the overall PDAP and has identified the desired MOEs, tools, assumptions, and parameters for the various stages of the project. Now, the manager must identify how the outputs of the various analysis tools will be utilized. Table 7 provides an overview of how the outputs of the selected tools are utilized in each stage.

Table 7. Utilization of tool outputs for HOV/HOT lanes case study.

Project Development Stage	MOEs	Selected Tool	Utilization of Outputs
Project need/initiation	System and facility MOEs	Travel demand model supplemented with sketch planning model	Only the travel demand model produced MOEs are reported. The sketch planning outputs are used to modify the travel demand model inputs.
Project clearance	System MOEs	Travel demand model supplemented with sketch planning model	Only the travel demand model produced MOEs are reported. The sketch planning outputs are used to modify the travel demand model inputs.
	Facility MOEs	HCM (or optimization model) supplemented with microsimulation	Only the HCM produced MOEs are reported. Microsimulation is used to modify the HCM inputs for the HOT lane access points.
PS&E, construction, and operation	System MOEs	Not applicable	System effects were dealt with in previous stage.
	Facility MOEs	HCM or optimization tools	Only the HCM produced MOEs are reported. Microsimulation is used to modify the HCM inputs for the HOT lane access points.

Notes: The selected system MOEs are VHD, average speed, mode split, and VMT by speed bin. The selected facility MOEs are delay/vehicle, level of service, planning time index, HOV volumes, transit patronage, collision rate during construction, and collision rate after open.

In the project needs and initiation stage, the primary tool is the travel demand model. At this stage, this tool is the only source of reported MOE results. The sketch planning model is used in a supporting role to determine how the demand model inputs should be modified in light of HOT lane considerations. The demand model forecasts for the facility provide the controlling total of SOVs using the facility. The sketch planning model allocates SOVs between the HOT lanes and the mixed-flow lanes.

In the project clearance stage, the demand model is the primary tool for predicting all demands and also for predicting MOEs at the system level. The demand model MOEs for facilities in the vicinity of the proposed project is compared to more precise HCM estimates and reconciled. Once this reconciliation check has been done, the demand model MOEs can be relied upon for the system performance results.

A combination of models are used for facility-level MOEs. For reporting freeway results, the freeway HCM tool (in this case, FREQ) is used. For reporting adjacent surface street results, the street optimization tool (in this case, Synchro) is used. Both tools overlap at the freeway ramps. On-ramp MOEs are taken from the freeway HCM tool. Off-ramp MOEs (which are controlled by the downstream signal) are taken from the street optimization tool.

The targeted simulation results for the HOT lane access points are used to modify the HCM inputs (e.g., capacities and speeds) for the access points. Thus, the simulation MOEs are used to modify the HCM inputs. The HCM freeway analysis tool can then be used to generate the freeway MOEs.

For the PS&E, construction, and operation stages, the same approach is used for utilizing tool outputs as described for the project clearance stage.

CHAPTER 7. VISUALIZATION AND COMMUNICATION AIDS

Throughout the course of the traffic analysis sequence and life cycle of project delivery, effective communication between members of the analysis team and others contributing to the project can eliminate significant sources of inconsistency. Communicating results to those beyond the study team must also be done in an effective manner.

This chapter presents an overview on communicating technical information, challenges to the effective use of analysis, general guidance on communicating technical information, data presentation techniques, guidance on writing technical reports, advice on preparing technical presentations, information on using software displays and animations, and a discussion of presenting and explaining inconsistent results.

Technical presentations can take the form of presenting to a small department-level working group, to a larger group within the organization, to an interagency group of transportation professionals, or to public stakeholders and decisionmakers.

TIPS FOR PRESENTATIONS OF TECHNICAL DATA

A guiding principle for preparing presentations should be that they do not have to be original but they must be accurate. Be sure to use analytical data to convey points. For clarity, remember that although non-technical decisionmakers may be busy, they are not stupid. Examining how newspapers like the *New York Times* or *Wall Street Journal* report complex technical information to a wide audience can serve as a guide for developing presentation material. Edward Tufte presents the following tips for presentations.[10]

Be able to describe the problem, its relevance, and the solution. Prepare at least one paragraph devoted to each of these in advance of the presentation.

Prepare and distribute a handout containing the essential details of what the presentation will cover. That way, the most important elements are there, the audience all will have received it in the handout, and if the presentation derails, the important topics are still covered. A preferred format for the handout is an 11-by-17-inch sheet folded in half, prepared in booklet form. This makes for a nicely structured summary of the presentation.

The audience should know beforehand what is going to be presented. Then, they can evaluate how the verbal and visual evidence supports the argument. Near the beginning of the presentation, tell the audience the following details:

- What the problem is.
- Why the problem is important.
- What the solution to the problem is.

If a clear statement of the problem cannot be formulated, the content of the presentation will be deficient. Give the audience many chances to get the point. Repeated variations on the same theme will often clarify and develop an idea. Additionally, characterizing and respecting the audience helps the presenter avoid underestimating or pandering to the audience.

To explain complex ideas or data, use the method of PGP: particular, general, particular. For example, to help the audience understand a multivariate table of data, briefly introduce the table and point to a particular number and say what it means. Then, step back and describe the general architecture of the table. Finally, reinforce it all with a second particular, explaining what another number means. The two particulars can be selected to make a substantive point as well as to explain the data arrangement. With PGP, the argument is more credible, as there is more than a single anecdote to accompany the general theory. An example would include presenting vehicle delays, volume-to-saturation flow rate ratios, and queuing at a signalized intersection. Start by discussing the specific information for one of the critical movements (e.g., a left-turn movement) by highlighting the delays and how the queuing results compare to the available turn pocket storage length. Next, discuss the general outline of the presentation of the data by explaining the locations of these data across the board for all movements. Then, point out another specific movement, perhaps another critical movement on the cross street.

Seek to maximize the rate of information transfer to the audience. Rather than just reading aloud from images projected from a computer, give everyone in the audience one or more pieces of paper packed with material related to the presentation. Handouts can show pictures, diagrams, data tables, research methods, references, or the complete text of the paper outlined in the talk. Unlike projected images, permanent and portable paper has credibility. This also has consistency benefits by conveying more detail of the analysis to others who may employ it as part of their future project work.

Analyze the details of the presentation. Then, master those details by practice, practice, practice. Good teachers know the value of preparation and practice.

Plan arrival and departure so as to make a difference. Show up early, and finish early. By arriving early the physical elements of the presentation can be prepared and presenters can adjust to the specifics of the room. Greet people as they arrive. Finishing early will rarely, if ever, garner any complaints from your audience.

Test for the integrity of the content being presented. Ask the following questions:

- Is the display revealing the truth?
- Is the representation accurate?
- Are the data carefully documented?
- Do the methods of the display avoid spurious readings of the data?
- Are appropriate comparisons and contexts shown?

Following these tips for presentations will help communicate analysis results in a more effective manner and promote consistency.

USING SOFTWARE DISPLAYS AND ANIMATION

Visual displays from transportation analysis software can be used to convey key information about the project's characteristics and analysis results. Transportation analysis software tools output many different types of reports, graphical displays, and animation videos. These outputs vary by classification, purpose, and sophistication level of the software program. These values can be compared among the various study alternatives.

Travel Demand Models

Graphical plotting options of travel demand models are useful for presenting analysis results. These can take the form of plots displaying network characteristics such as number of lanes and volume-delay functions, volume plots, thematic maps, zonal pie charts, isochrones, scatter plots, and matrix visualizations. Through these types of presentations, as well as tabular output, travel demand models can be used to display the following:

- Traffic volumes (totals, deltas between scenarios).
- Volume-to-capacity ratios.
- VMT.
- VHT.
- Mode shares (by trip purpose or by geographic subarea).
- Trip length frequencies.
- Delays.

Traffic Signal Optimization Tools

Analysis results from traffic signal optimization tools can be displayed using graphical outputs in the form of time-space diagrams depicting cycle lengths, splits, coordination, and offsets.

Simulation

Microsimulation software tools include animation, video representations of the traffic operations being modeled. These videos are visually powerful presentation tools that can be saved in a file format that does not require the underlying simulation software when replaying them (generally in the form of .avi files). These files can then be embedded within Microsoft PowerPoint® presentations for ease of playback and portability during a presentation.

In previous projects, analysts found that displaying visual presentations of their simulations using two-dimensional and three-dimensional .avi files before submitting the written technical report was a good step. The presentation showed that the model reflected real-world conditions of queuing and hot spots.

OVERVIEW ON COMMUNICATING TECHNICAL INFORMATION

Traffic analyses result in a plethora of output data. Deciphering which outputs are important for evaluating a project's purpose and which are not, as well as evaluating which resulting values of these outputs are reasonable or not, are critical roles of analysts and project managers.

The analyst is charged with proactively providing useful information on a timely basis. Analysts can help support projects by using an array of communications tools. The effective communication of technical information can also encourage two-way communication with stakeholders, providing an additional level of error-checking and interpretation of results to the traffic analysis process. Moreover, effective communication also fosters teamwork and goodwill because keeping an audience well-informed reduces negative interaction.

It is not common for analysts' training to focus on the skills that support high-quality presentations. Although agencies tend to have some standardization in the type and content of studies and reports required through the project life cycle, the focus on presentation can be uneven. Some agencies provide templates for report organization or tables of contents, but even where templates are provided, guidance for adapting templates to specific study objectives is sparse.

During the planning stages of analysis, when the audience may include political decisionmakers, it is apparent that more attention is paid to communication. In the course of design, environmental analysis, and operational assessments, effective communication can eliminate considerable sources of inconsistency. Effective presentation and communication within and between organizations is regarded as a distinct discipline and in other professional fields (particularly the private sector) managers are expected to have some proficiency in these areas.

CHALLENGES TO THE EFFECTIVE USE OF ANALYSIS

Analysis tools provide data in a wide variety of formats, some of which are tremendously voluminous. Requirements to postprocess some of the output adds even more. The challenges inherent in presenting results coherently and documenting the analysis are complicated by the fact that the technical background of the audience, particularly, decisionmakers or other readers, may be limited.

Work that is not successfully communicated loses a considerable amount of its value. The fact that analysts and many project managers are not trained to present information can lead to perceived inconsistencies among readers and to real inconsistencies as analysis is passed along through the project life cycle.

Traffic analysis tools generate an array of outputs that can be used by analysts in reporting or communicating the results of their analyses, but several hindrances can appear based on differences in definitions, file formats, and organization of the outputs. This can lead to misinterpretation of analysis findings. Likewise, the value of the analysis process is demonstrated by the relevance the findings have for informing decisionmaking. Communicating findings effectively is, therefore, essential in order for the traffic analysis results to accurately influence policy decisions.

Guidance for communicating technical information, writing technical reports, and preparing technical presentations is provided in the following sections.

GENERAL GUIDANCE ON COMMUNICATING ANALYSIS

Determining the best tools and measures for decisionmaking depends on the purpose of the analysis. Decisionmaking audiences can generally be divided into three broad categories: public organizations, agency management, and agency technical staff. Public organizations include entities such as city planning commissions, city councils, community groups, and other boards. Agency management includes individuals at higher levels who may or may not be well-versed in technical analysis procedures. Technical staff includes engineering or planning analysts and project managers charged with performing or directly managing traffic analysis. Additionally, members of the general public are an audience to whom technical information needs to be communicated.

The results of traffic analyses can be difficult for decisionmakers to interpret unless the data, findings, and analytic interpretations are carefully organized and presented. In general, the results should be presented as simply as possible. This might include using a limited set of performance measures and providing the data in an aggregate form. However, while simplicity has its merits, the analyst should be careful when striving to simplify the message not to lose the ability to communicate the underlying variations and factors that generated the results.[8]

Decisionmakers who are not analytically oriented often prefer to have a single number or letter represent a condition. It is generally not effective to provide representatives of the public with a large set of differing measures or with a frequency distribution for a specific performance measure. If the analyst has several measures available, it is preferable to select the one that best fits the situation and to keep the others in reserve until needed.[8]

Decisionmakers who represent the public usually prefer measures that their constituents can understand. When selecting the measures to present, it is important for the analyst to recognize the orientation of the decisionmaker and the context in which the decision will be made. In general, these measures can be differentiated as system-user or system-manager oriented. When making a presentation to technical members of a public agency such as highway engineers and planners, it might be necessary to use more than one performance measure, especially when providing both the system-user and system-manager perspectives.[8]

Principles of Presenting Analysis Results

Simple and direct graphics reflect the fundamental principles of effective communication of results. Tufte describes eight of these principles.[10]

Principle 1: Comparisons

The first principle for analysis and presentation of data is to show comparisons, contrasts, and differences. Answer the question "compared with what?" (Such as the "do nothing" case.) Whether evaluating changes over space or time, adjusting and controlling for variables, designing experiments, or doing just about any kind of evidence-based reasoning, the essential point is to make intelligent and appropriate comparisons. In traffic analysis, comparisons can be made between "project" and "no-project" scenarios, between various analysis forecast years, and between peak and off-peak conditions, among others. It is important to present these comparisons consistently. The benefit of consistency is that decisions can then be made based on logical criteria that are evident and replicable.

Principle 2: Causality, Structure, Explanation

Fundamental intellectual tasks should be addressed in the analysis of the output results. The second principle for the analysis and presentation of data is to show causality, explanation, and systematic structure. Describe the causal variables at play and how they affect outcomes. In traffic analysis, describe how variations in traffic volumes affect operating conditions, how capacity improvements affect travel speeds and delays or induce latent demand, or how freeway ramp metering or traffic signal optimization affects delays and throughput, among others. Having a consistent structure for presenting the analysis will more effectively establish the relationship between key variables and major findings. The audience will find it easier to understand the implications of the analysis, and recommendations will be more persuasive.

Principle 3: Multivariate (Complex) Analysis

Most topics of inquiry are multivariate (involving three or more causal variables). Transportation analysis is no exception. Describing and displaying the interplay and effects of the many variables in your analysis can yield a more thorough reasoning and understanding of the results. If relationships are not explained, the audience may get lost and fail to understand the interactions between important concepts. Be clear, but avoid oversimplifying the problems when presenting results. Make sure to explain the effects of complexity and how they were accounted for.

Principle 4: Integration of Evidence (Tell a Complete, Coherent, and Consistent Story)

Words, numbers, pictures, diagrams, graphics, charts, and tables belong together. For example, good maps routinely integrate words, numbers, artwork, grids, and measurement scales. The fourth principle for the analysis and presentation of data is to completely integrate words, numbers, images, and diagrams. Tables of data can be thought of as paragraphs of numbers and can be tightly integrated with the text for the convenience of reading rather than segregated in an appendix. Annotate images and tables in your presentations with explanations of what is going on. When presenting text and data analysis, this integration can be accomplished in layers. At first, the data can be presented as standalone points to cleanly and clearly show the data. Then, layering techniques can be employed to add the other information to the presentation.

Principle 5: Clear and Complete Documentation

The fifth principle for the analysis and presentation of data is to thoroughly describe the analysis results. Documentation is essential for quality control in such displays. Thorough documentation is a good sign that a report was constructed with some care and craft. Documentation should be integrated with presentation materials using footnotes in reports and legends in figures. Authorship credit should also be included. Displays should name their data sources. Viewers should be informed about the scales of measurements on data graphics. This requires referencing any policies that establish and justify an advocacy position on the part of report authors. Communicating the policy and other background related to qualitative or subjective statements allows the audience and other analysts to refer to that background when similar situations occur, which promotes consistency. Point out potential conflicts of interest. Thorough documentation allows more effective review. Provide a detailed title, indicate authors and sponsors, document the data sources, show complete measurement scales, and point out relevant issues.

Principle 6: Content Counts Most of All

Good knowledge of the content and a deep caring about the substance of the analysis promotes excellent analytical documentation and communication. Analytical presentations ultimately stand or fall on the quality, relevance, and integrity of their content. The most effective way to improve a presentation is to get better content. Formatting gimmicks cannot salvage failed content. The most important question when constructing analytical presentations should be "What is this display is supposed to communicate?" Ensure that the main ideas are communicated without superfluous distractions. Distractions lead to inconsistencies. Bad decisions are made when the audience is distracted from the main point.

The preceding principles are implemented in the creation of data presentations by the analyst for inclusion in written reports and presentations of technical information.

DATA PRESENTATION TECHNIQUES

Transportation reports and presentations typically convey significant amounts of data representing a variety of information from the input stage through the results stage of analysis, as well as result summaries. The data are often represented in illustrations such as tables, figures, and diagrams, which are efficient and powerful ways to present the results. It is crucial, however, that these elements convey their intended messages. Properly designed illustrations succinctly and poignantly present key elements of the study in a manner that is both approachable and enlightening to the reader. Poorly designed illustrations can fail to communicate the relevant information and can confuse and distort the data or results. Table 8 presents an overview of the guiding principles for selecting techniques to display data.

Table 8. Quick guide to data presentation techniques.

Use	To Show	Principle
Table in text	Summary of output data central to theme of report	1, 2, 3, 4, 5, and 6
Table in appendix	Summary of research materials serving as background to analysis	4 and 5
Bar charts	Comparison of the value of different items at specific points in time or at specific physical locations	1, 4, 5, and 6
Line graphs	Display of time series and trend data	1, 4, 5, and 6
XY graphs	Display of relationships among two or more series of data points where the intent is to show general relationships via clouds of points rather than explicit lines	1, 2, 4, 5, and 6
Pie charts	Relative distribution of each value to the whole of a single series of data	1, 4, 5, and 6
Area graphs	Display of data showing parts or shares and the whole and how they change over time	1, 4, 5, and 6
Thematic maps	Locations of a variable over a geographical area	1, 4, 5, and 6
Flow charts	Depiction of processes or procedures, denote certain types of actions, activities, or decisions in the process	1, 2, 4, 5, and 6
Progress charts	Time schedule for a study or project	4, 5, and 6
Diagrams and maps	Depiction the project's study area, its physical features, and a host of project-related information	1, 2, 3, 4, 5, and 6

When creating illustrations, consider the following:

- What illustrations are most suitable for the intended audience based on the data and purpose of the study?
- What form of tables or graphics would most clearly illustrate the message?
- How informative and legible are the illustrations?
- How readable is the layout? Do the font type and size allow for easy scanning and reading for those in the back of the room in a presentation or for the typical reader of a report?

Bar Chart

A bar chart uses vertical and horizontal bars to represent each value in a series. They are typically used to compare the value of different items at specific points in time or at specific physical locations.

Line Graph

Line graphs connect each value in a series with a line. Line graphs are used to display time series and trend data. Care needs to be given to be certain that non-continuous data do not imply continuity in the data.

XY Graphs

XY graphs display relationships among two or more series of data points where the intent is to show general relationships via clouds of points rather than explicit lines. Plots may display only data points, a line without the data points, or a best-fit line overlaid on the points.

Pie Charts

Pie charts show the relative distribution of each value to the whole of a single series of data. They work well when there are a limited number of items making up the pie. Bar charts work better when there are too many items to display well in pie form. Pie charts are best when the desire is to show the proportionate or percentage contribution of each item toward the total. They help the reader quickly separate the major items from the minor items.

Area Graph

Area graphs present each series as an area of the chart. These areas can be filled in using a variety of coloring, gradations, or hatchings. Data series are stacked vertically, rather than shown side-by-side. This works best for displaying data showing parts or shares and the whole. This also shows changes over time.

Thematic Maps

Thematic maps show the locations of a variable over a geographical area. An example would be a State map depicting vehicle registrations per 1,000 population within each county, with county boundary lines.

Flow Charts

Flow charts depict processes or procedures. Triangles, boxes, ovals, circles, and other shapes are used to denote certain types of actions, activities, or decisions in the process. Lines with arrows show possible actions. An example is a flow chart displaying the decision-making process for which class of software tools is most appropriate for a particular type of project analysis.

Progress Charts

Progress charts depict the time schedule for a study or project. The time span of the project is displayed on the horizontal axis in appropriate increments (weeks, months, quarters, etc.). Each task is displayed as a horizontal bar spanning the duration of time for which the task should take place. These charts are also known as Gantt charts. They are used in scoping as project planning tools as well as employed to check the progress of the various tasks as the project proceeds.

Diagrams and Maps

Diagrams or maps depict the project's study area, its physical features, and a host of project-related information. Study area limits, roadway geometry and lane striping, traffic volume data, and intersection control type are examples of the information that can be displayed in such figures.

RESOURCES FOR FURTHER READING

There are many useful resources for presenting technical analyses and writing technical reports. The following is a partial list:

- Institute of Transportation Engineers, *Manual of Transportation Engineering Studies,* Washington, DC, 2000.
- Institute of Transportation Engineers, *Traffic Engineering Handbook, 6th Edition*, Washington, DC, 2009.
- Silyan-Roberts, H., *Professional Communications: A Handbook for Civil Engineers,* American Society of Civil Engineers, Washington, DC, 2005.
- Strunk, W. and White, E.B., *The Elements of Style, 4th Edition,* Longman, Old Tappan, NJ, 1999.
- Tufte, E., *Beautiful Evidence,* Graphics Press, Cheshire, CT, 2006.
- Tufte, E., *The Visual Display of Quantitative Information*, Graphics Press, Cheshire, CT, 2001.
- Tufte, V., *Artful Sentences: Syntax as Style*, Graphics Press, Cheshire, CT, 2006.

CHAPTER 8. CONCLUSION

The result of this study was to provide recommendations on the management, planning, and conduct of traffic analysis that will promote greater traffic analysis tool consistency over the typical project development life cycle. It has been directed toward professionals operating in State departments of transportation and other agencies responsible for transportation project development and delivery.

A transportation improvement project typically goes through the following six stages in the development life cycle, although this varies by transportation agency:

1. Project need identification.
2. Project initiation.
3. Project clearance.
4. PS&E.
5. Construction.
6. Operation.

In the early stages of project development, relatively little has been defined about the project. Consequently, the traffic analysis has to be relatively broad and comprehensive in the early stages, with the focus of the analysis increasing as the project and its alternatives are better defined in the later stages.

The key to managing consistency of the traffic analyses throughout the various stages of project development is a PDAP that is scaled to the needs of each stage of the process. The PDAP is a scalable master scope that describes the project, its purpose, and the objectives of the traffic analysis. It identifies the MOEs that are used to evaluate the project and its alternatives, describes the traffic analysis approach (including tools, assumptions, and parameters), identifies the risks and contingency plans for dealing with those risks, determines the resource requirements, and lays out the time schedule for the analysis. This document has provided details and advice on the contents of the PDAP as well as information on how to utilize outputs from different analysis tools and visualization and communication aides.

APPENDIX. TRAFFIC ANALYSIS TOOL REFERENCES

This appendix describes a few useful references on the application of traffic analysis tools.

GENERAL GUIDANCE

The FHWA's *Traffic Analysis Tools Program* Web site provides a comprehensive set of resource documents for selecting and applying traffic analysis tools.[(1)] The site can be found at http://ops.fhwa.dot.gov/trafficanalysistools/index.htm.

The first two volumes are particularly useful for selecting among traffic analysis tool types. The volumes are as follows:

- Volume I: Traffic Analysis Tools Primer.
- Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools.
- Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software.
- Volume IV: Guidelines for Applying CORSIM Microsimulation Modeling Software.
- Volume V: Traffic Analysis Toolbox Case Studies—Benefits and Applications.
- Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness.
- Volume VII: Predicting Performance with Traffic Analysis Tools.
- Volume VIII: Work Zone Modeling and Simulation—A Guide for Decision-Makers.
- Volume IX: Work Zone Modeling and Simulation—A Guide for Analysts.
- Volume X: Localized Bottleneck Congestion Analysis Focusing on What Analysis Tools Are Available, Necessary, and Productive for Localized Congestion Remediation.
- Volume XI: Weather and Traffic Analysis, Modeling, and Simulation.

SKETCH PLANNING MODELS

Volume V of the FHWA's *Traffic Analysis Tools Program* includes a brief case study of an application of sketch planning for interchange analysis in Eugene, OR. The FHWA Decision Support Methodology spreadsheet identifies a number of sketch planning tools. Section 3.1 of the British Department of Transport's Web-based *Transport Analysis Guides* provides a description of spatially aggregate models and specifies when these should be used.[(11)]

TRAVEL DEMAND MODELS

The FHWA has created the Travel Demand Modeling Improvement Program to support good practices in travel demand modeling. The resources Web page provides recommended reading, technical references, and a clearinghouse of documents on travel demand modeling and can be found at http://tmip.fhwa.dot.gov/.[12]

HCM TOOLS

The introductory sections to each of the methodological chapters in volumes 2 and 3 of the 2010 HCM list the limitations of the methodologies described in the manual.[8] Chapter 6 in volume 1 directly addresses traffic analysis tools with descriptions of tools, guidance on the selection of tools, and guidance on their use. Chapter 7 addresses the presentation and interpretation of results with specific guidance on addressing uncertainty in the interpretation of analysis.

The HCM applications guide, located in the volume 4 technical reference library of the 2010 HCM details case studies that cover the fundamental applications of various methodologies. The applications guide is directed toward new users of the manual.

SIMULATION MODELS

FHWA Guides

Volumes III and IV of the FHWA's *Traffic Analysis Tools Program* provide guidance on the development, calibration, and validation of microsimulation models. Volumes I and II of the same toolbox series provide guidance on the selection of microsimulation.[1]

Minnesota Department of Transportation CORSIM Guideline

The Minnesota Department of Transportation relies on CORSIM for most of its corridor studies and has developed a CORSIM modeling and calibration guideline based on the FHWA simulation modeling steps.[13] Prior to modeling, the guideline provides tips for scoping the project and whether or not a CORSIM analysis is appropriate. The second part of the guideline discusses base case modeling techniques, calibration, and alternatives analysis. Support beyond this guideline is also available online, where past projects, sample tables, and screenshots as well as CORSIM input files are available.

Oregon Department of Transportation Simulation Guideline

The Oregon Department of Transportation (ODOT) developed a traffic simulation guideline for four of its most commonly used software packages, including SimTraffic, VISSIM, PARAMICS, and CORSIM.[14] The SimTraffic guideline is by far the most thorough of all four, discussing topics including data recommendations, default values, common parameters, and data outputs. ODOT requires that VISSIM/PARAMICS submittals (i.e., volumes, signal timings) from consultants be converted to Synchro for more effective review.

NCHRP 3-85 Final Report

The final report for NCHRP 3-85, *Guidance for the Use of Alternative Traffic Analysis Tools in Highway Capacity Analyses*, provides guidance on the selection and use of alternative traffic analysis tools to the HCM.[9] The report reviews how level of service is derived from simulation model outputs and the appropriateness of doing so. It develops methods for translating MOEs between different analysis tools and develops guidelines for the use of DTA tools.

INTERNATIONAL GUIDES

United Kingdom Transport Analysis Guide

The Ministry of Transport has sponsored a Web-based *Transport Analysis Guide* that provides general guidelines for the conduct of transport studies.[11] Section 2 is directed toward project managers and is very broad in scope. This guidance addresses the scoping of analysis, stakeholder participation strategies, and policy options and strategies as well as a framework for cost-benefit analysis and summaries of a variety of modeling applications. Section 3 is addressed to experts and provides a more detailed overview of the appropriate stages of analysis as well as input and policy output requirements. Methodologies are addressed at the level of theory. References to other more detailed documentation are included throughout.

London Transport Assessment Best Practice

Transport for London has issued guidelines for transport assessments required of major developments under its planning authority.[15] This includes a review of the criteria used for requiring assessments. The specific guidance addresses scoping, study and report organization, and recommended methodological approaches.

Australia—*The Use and Application of Microsimulation Traffic Models*

Austroads prepared a research report that explores the limitations of microsimulation traffic models and provides a list of appropriate problems amenable to microsimulation analysis.[16] Furthermore, the report provides some background on a variety of microsimulation software packages and reviews criteria for selecting among these. The report addresses good practices for model validation and calibration. The report includes a pro forma for the formalized auditing of microsimulation models. The report is also appended by guidance on the scoping of microsimulation analysis under the heading “Preparing a Brief for Microsimulation.”

Japan—*Standard Verification Process for Traffic Flow Simulation Model*

A draft report from the Japanese Society of Traffic Engineers provides an overview of the microsimulation modeling process, discusses appropriate applications for microsimulation, and reviews model verification techniques.[17] The paper makes a distinction between verification and validation, indicating that the first is a process of evaluating the reproducibility of theoretical results with model results based on virtual data sets whereas the latter deals with the reproducibility of observed travel characteristics using actual data. The paper discusses verification and validation in detail.

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REFERENCES

1. *Traffic Analysis Tools Program*, Federal Highway Administration, Washington, DC, 2011. Accessed online: April 25, 2011. (http://ops.fhwa.dot.gov/trafficanalysistools/index.htm).

2. *Project Development Procedures Manual (PDPM)*, California Department of Transportation, Sacramento, CA, 2010. Accessed online: April 25, 2011. (http://www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm)

3. *Systems Engineering Guidebook for Intelligent Transportation Systems*, Version 3.0, California Department of Transportation and Federal Highway Administration California Division, Sacramento, CA, 2009. Accessed online April 25, 2011. (http://www.fhwa.dot.gov/cadiv/segb/files/segbversion3.pdf)

4. Federal Highway Administration. "FHWA Resource Center." Washington, DC, 2011. Accessed online: April 25, 2011. (http://www.fhwa.dot.gov/resourcecenter/)

5. Federal Highway Administration. "Operations Performance Measurement Program." Washington, DC, 2010. Accessed online: April 25, 2011. (http://ops.fhwa.dot.gov/perf_measurement/index.htm)

6. *Travel Model Validation and Reasonableness Checking, Second Edition.* Federal Highway Administration, FHWA-HEP-10-042, Washington, DC, 2010. Accessed online: April 25, 2011. (http://tmip.fhwa.dot.gov/resources/clearinghouse/docs/FHWA-HEP-10-042/index.htm)

7. Chiu, Y., Bottom, J., Mahut, M., Paz, A., Balakrishna, R., Waller, T., and Hicks, J. *A Primer on Dynamic Traffic Assignment, ADB30, Transportation Network Modeling Committee,* Transportation Research Board, Washington, DC, 2010. Accessed online: April 25, 2011. (http://www.fsutmsonline.net/images/uploads/mtf-files/dta_primer.pdf)

8. *Highway Capacity Manual*, Transportation Research Board, Washington, DC, 2010.

9. National Cooperative Highway Research Program. *Guidelines for the Use of Alternative Traffic Analysis Tools*, NCHRP Project 3-85, Transportation Research Board, Washington, DC, 2010.

10. Tufte, E., *Beautiful Evidence*, Graphics Press, Cheshire, CT, 2006.

11. *Analysis Procedures Manual*, Oregon Department of Transportation, Portland, OR, 2011.

12. Federal Highway Administration. "TMIP Travel Model Improvement Program." Washington, DC, 2011. Accessed online: April 25, 2011. (http://tmip.fhwa.dot.gov/)

13. Minnesota Department of Transportation. "Corridor Simulation Modeling—Requirements and Resources." St. Paul, MN, 2011. Accessed online: April 25, 2011. (http://www.dot.state.mn.us/trafficeng/modeling/modelreq.html)

14. Department for Transport. "Transport Analysis Guidance—WebTAG," London, UK, 2010. Accessed online: April 25, 2011. (http://www.dft.gov.uk/webtag/index.php).

15. *Transport Assessment Best Practice Guidance*, Transport for London, London, UK, 2010.

16. *The Use and Application of Microsimulation Traffic Models*, Austroads, Sydney, Australia, 2006.

17. *Standard Verification Process for Traffic Flow Simulation Model*, Japan Society of Traffic Engineers, Tokyo, Japan, 2002.

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