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NATIONAL COOPERATIVE
HIGHWAY RESEARCH PROGRAM REPORT

263

Simplified Procedures For Evaluating Low-Cost TSM Projects

User's Manual

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT **263**

SIMPLIFIED PROCEDURES FOR EVALUATING LOW-COST TSM PROJECTS

USER'S MANUAL

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TRANSPORTATION RESEARCH BOARD
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WASHINGTON, D.C. OCTOBER 1983

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the National Academy of Sciences, or the program sponsors.

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FOREWORD

By Staff
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This manual is for use by transportation planners, traffic engineers, and transit operators involved in planning, programming, and implementing all types of low-cost transportation improvements. Although it is oriented to near-term improvements in urban areas of all sizes, the approach and information presented also may be of interest to agencies engaged in longer range, rural or statewide planning and implementation. The manual presents guidelines and recommendations on approaches and procedures for (1) identifying and assessing problems, (2) identifying and screening potential solutions to these problems, (3) determining the information needed to make design and operational decisions, (4) selecting and applying techniques to produce this information, and (5) formulating priority improvement programs.

The body of information on developing, assessing, and implementing TSM actions has grown significantly in recent years. Studies have addressed the planning, design, and operation of TSM improvements; presented techniques for analyzing general types of improvements; and assessed the likely impacts of different TSM measures. In addition, the U.S. Department of Transportation has sponsored demonstrations of several TSM options and disseminated results to state and local planning agencies.

Nevertheless, there is still general consensus among practitioners that a number of problems remain with procedures for identifying, evaluating, and implementing low-cost TSM projects. The applicability of many proposed actions, the complexity of many analytic methods, the responsiveness of planning activities to the immediacy of TSM, and the difficulties in establishing priorities among projects are problems frequently cited by transportation agencies responsible for TSM project development, programming, and implementation. The need for simplified procedures that address these problems was the impetus for this research (NCHRP Project 7-11).

The research reviewed existing procedures and techniques for evaluating proposed TSM actions and developing priority programs of these actions. Few gaps were identified, with most related to limited information on the actual performance of TSM actions in different settings. More serious deficiencies were noted in when and how techniques were applied, and in the overall approach commonly taken to planning and programming TSM actions. The research effort responded to these deficiencies by (1) developing a planning/programming framework well suited to the low-cost and quick-response objectives of TSM, (2) summarizing information to help agencies identify appropriate TSM solutions to common problems and screen these potential actions for applicability in local settings, and (3) preparing guidelines to help agencies determine the information needed to evaluate proposed actions and select appropriate techniques for preparing that information.

This manual presents the research findings in a form directly applicable by transportation professionals at municipal, regional, and state agencies. It documents a practical, problem-oriented approach to identifying, developing, evaluating, and programming TSM actions. Its tables, guidelines, and information summaries will assist agencies in applying the approach to identify feasible, workable, and low-cost solutions to near-term problems in their communities. Analysis procedures are presented that will help agencies develop potential solutions into packages ready for programming and implementation, and sample applications and case studies illustrate their use.

The research conducted as background for preparation of the manual is documented in a separate report: "Low-Cost TSM Projects; Simplified Procedures for Evaluation and Setting Priorities." That report is not published in the regular NCHRP report series, but a limited number of copies are available at a cost of $6.00 per copy (or microfiche may be purchased at a cost of $4.50) upon written request to the Cooperative Research Programs, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418. In addition to describing the scope, approach, findings, conclusions, and recommendations of the research, the agency report contains the following supporting material:

- Responses to questionnaires and interviews conducted to determine the responsibilities, resources, needs, and perceptions of agencies involved in planning, programming, and implementing TSM actions.
- An annotated bibliography of literature reviewed in conducting the study.
- A review of packaging and programming techniques.
- A review of action classification schemes and other procedures used to identify and screen TSM actions.

CONTENTS

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This manual was prepared as part of NCHRP Project 7-11 by Multiplications, Inc., in association with SG Associates, Inc., and Herbert S. Levinson.

James H. Batchelder, Senior Transportation Analyst, Multisystems, Inc., was the principal investigator and author of this manual. The other principal authors, were Marvin Golenberg, Principal, SG Associates, and Herbert S. Levinson, Consultant. Jane A. Howard, Associate, SG Associates, compiled much of the reference material required to produce the manual, contributed to the formulation and testing of project planning procedures, and drafted sections of the manual.

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SIMPLIFIED PROCEDURES FOR EVALUATING LOW-COST TSM PROJECTS

USER'S MANUAL

SUMMARY

Many problems exist with approaches commonly taken in planning and programming low-cost transportation improvements, and with procedures available to support these activities. Too frequently, transportation systems management, or TSM, has been viewed as a checklist or catalogue of actions, even though many actions are inappropriate in specific situations faced by most transportation agencies. Undue emphasis has been placed on unique and exotic actions, instead of on practical approaches to addressing observable and resolvable problems. Although workable, low-cost actions have been implemented in most urban areas, TSM planning also has produced "wishlists" of projects that will take years to implement and projects that have proven inoperable.

The problem-oriented approach to short-range planning and programming presented in this manual can be applied to avoid these problems. In this approach, low-cost transportation improvements are explicitly considered as versatile means of resolving specific problems, improving operational efficiency, or accommodating anticipated near-term growth and development. Planning and project development efforts are focused on the following tasks:

- Understanding the operations of specific transport facilities and services and determining the underlying causes of identified problems.
- Carefully screening actions, so only feasible, acceptable, and potentially effective solutions are considered.
- Refining candidate actions into detailed physical, operational, and other changes that are tailored to specific problems and sites.

The approach also introduces financial considerations and policy objectives early in the planning process. Problems and resources for their resolution are regularly reviewed by a community or agency, allowing realistic priorities, objectives, and expectations to be established.

In addition to presenting the recommended approach and illustrating its application in situations typically faced by state, regional, and municipal agencies, the manual contains an extensive Reference Handbook compiled to support agencies in applying the approach. The handbook contains tables, guidelines, notes, literature references, and other information sources prepared to help agency staff in the following aspects of project planning:

- Identifying and screening potential solutions to problems they are attempting to resolve.
- Determining the information needed to make project design decisions.
- Selecting and applying appropriate techniques to produce this information.

Organization of the Manual

The manual is organized into three parts so that it can function both as a procedural or instructional guide and as a reference manual; their contents are briefly described as follows:

- Part I -- Introduction and Procedural Guide. Chapter One briefly summarizes the problems in TSM that led to the development of this manual, and introduces the approach recommended for planning and programming low-cost transportation improvements. Chapter Two describes strategic management activities conducted by transportation agencies, and recommends changes in the activities that will improve the efficiency and effectiveness of an agency's short-range planning and programming efforts. Chapter Three presents an engineering or design approach to project planning and development that is recommended for application within the strategic management framework, and discusses some key issues in the analysis and evaluation of proposed projects. Chapter Four provides an example application of the recommended project planning procedure, and shows how material in the Reference Handbook is applied in project analysis and design.

- Part II -- Reference Handbook. The handbook contains tables, guidelines, information sheets, and other aids compiled to assist projects planners and engineers in identifying, screening, analyzing, and evaluating TSM actions. The contents are organized as follows:

  Screening Aids

  - Action identification tables that provide general approaches and types of TSM actions to consider for solving several typical problems.
  - Profiles on various actions that present conditions where they are applicable and effective, issues and potential problems to consider in their design and operation, factors to be considered in their analysis and evaluation, and sources of more detailed information on their design and performance.

  Impact Estimation and Analysis Aids

  - Guidelines on developing efficient analysis plans and selecting relevant performance measures.
  - Method selection tables that identify appropriate techniques for estimating measures in different planning situations.
  - Notes that describe and illustrate simplified or refined estimation techniques that are not presented in readily available literature.

  Additional Planning and Evaluation Aids

  - Notes on various problem assessment, packaging, and program development techniques, including benefit/cost and cost-effectiveness analysis.
  - Information sources including a basic reference library for planners in small communities and addresses of agencies that distribute information on TSM actions and analysis procedures.

- Part III -- Applications. Five case studies are presented that show how the recommended approach to project planning and program development can be adapted to different situations.

The manual is not intended as a stand-alone reference; indeed, it could not be self-contained and cover the breadth of TSM. It attempts to compile a lot of information in a useful form, but frequently refers users to other documents for more detailed information on TSM actions and analysis techniques. The manual should be treated as a working document, with users adding references, action profiles, notes on techniques, case studies, and other information to meet their specific needs.

Readers' Guide

- Agency administrators of short-range management and planning functions should review Part I. The discussion of strategic management activities in Chapter Two will be of particular interest, because it recommends changes that should improve the efficiency and effectiveness of the agency's short-range project planning and priority programming activities.

- Project managers should read Part I, especially the recommended approach to project planning presented in Chapter Three. They also should review Parts II and III so they can assist project staff in applying the manual in specific planning studies.

- Engineers and planners engaged in project planning and development should read Chapters Three and Four of Part I to understand the recommended approach, and review some of the applications presented in Part III. Part II should be reviewed to gain enough familiarity with its contents so it can be used as a reference document in the course of project planning.

- General readers may find Part I useful in understanding the procedures and decisions involved in planning and programming low-cost transportation improvements. The Screening Aids and Information Sources in Part II will be of interest to readers seeking information of specific actions and their applicability to local situations.

PART I
INTRODUCTION AND PROCEDURAL GUIDE

CHAPTER ONE
A NEW APPROACH TO IMPLEMENTING TRANSPORTATION SYSTEMS MANAGEMENT

PURPOSE OF MANUAL

A growing body of literature describes the philosophy of Transportation Systems Management (TSM) and its role in the planning process, and sets forth technical procedures for classifying improvements and measuring their effectiveness. Too often, however, this literature overlooks the immediate-action nature of TSM actions and the limited data and staff resources available to most communities considering their implementation -- factors that mandate simplified, coordinative approaches to evaluating improvements and setting priorities.

The research leading to this manual also identified other problems with TSM planning that deal primarily with the general approach or framework often applied in developing and evaluating actions. Too frequently, TSM has been viewed as a planning process "requirement" rather than an action program. TSM actions often are proposed not as rational responses to identified needs or problems, but as concepts to be inserted blindly into a region's Transportation Improvement Program (TIP), independent of ongoing system improvement efforts. The actions have come to be considered almost for their own sake rather than as creative solutions to problems. In addition, their analysis frequently has been conducted in a framework designed for long-range policy and major capital planning, rather than for short-range problem solving leading to projects designed in sufficient detail for immediate implementation. As a result, TSM has beeen dismissed as irrelevant by large segments of the transportation planning and operations community, even in areas where it might effectively be applied.

The concept of TSM is not new; many of its components represent some 75 years of efforts by planners and engineers to improve the operational efficiency of transportation facilities and networks. Traffic engineering, parking management, transit service improvements, street use priorities, and various regulatory, pricing and operations management improvements have been designed and implemented in all sizes of communities. Many of these low-cost physical and operational improvements have been the focus of other programs such as TOPICS, Transit Development Planning, and High Hazard Locations. What is new in TSM is the emphasis on coordination, and the incorporation of a variety of managerial, regulatory and low-cost physical and operational actions into the transportation planning, funding, and implementation processes established by the U.S. Department of Transportation (USDOT) and other agencies.

The manual was developed to assist state, regional, and municicial agencies in using TSM as a means of solving near-term problems through the implementation of low-cost, workable, and publicly acceptable transportation improvements. It presents and demonstrates a practical approach to short-range planning and program development that can be applied to integrate TSM into an agency's on-going transportation planning and implementation processes. Its Reference Handbook draws on the profession's extensive experience with planning and implementating low-cost improvements; it provides tables, guidelines, and notes on TSM actions and their analysis, as well as references to reports and manuals covering specific aspects of TSM.

OUTLINE OF APPROACH

The approach is designed to guide the transportation agency in the planning of TSM projects by providing a series of logical steps that start with the identification and definition of a problem, and proceed through an increasingly detailed process of elimination and refinement of candidate actions until a workable solution is chosen, designed, programmed, and implemented. A focus on implementation enables the planner or engineer to systematically discard proposed actions that do not help solve the identified problem(s), and to mix and refine those that do until a solution is reached or found infeasible within the constraints imposed by the local situation (e.g., physical barriers or lack of funds to widen a right-of-way).

The attributes of most problems addressed by TSM actions are well defined, because they are based largely on direct observations and measurements of existing conditions or on specific development proposals. Operational, performance, travel, and other informational data useful in designing actions often are available from system inventories and monitoring or from previous studies, or can be collected through field measurements or interviews. In many instances, the actions and their potential effectiveness also are well known, and the design and analysis of many commonly implemented actions already have been codified in manuals regularly used by transportation agencies. Even when TSM actions are considered as part of a policy study (e.g., a study of actions to reduce regional energy consumption), the identification of specific problem areas, the existence of design standards or warrants, and a goal of near-term implementation often can serve to impose a project design focus on their analysis.

Its action orientation and detailed information base make TSM planning fundamentally different from long-range planning. The process used for TSM planning should reflect these differences, which are summarized in Table 1, and not mimic the comprehensive "alternatives analysis" process that has been developed for long-range planning. With few exceptions, it is not necessary to carry out extensive analysis and prepare tables displaying the many potential transportation, social and environmental consequences of alternative investments and policies to determine good, low-cost solutions to near-term problems.

A more fitting approach to TSM project planning is one in which the following questions are sequentially answered in arriving at a workable and acceptable solution (if any can be designed):

- Will the proposed actions solve the problems or meet primary planning objectives?
- If effective in solving the problems, do the actions help achieve other objectives of the agency or community?
- Can any community, environmental, or institutional impediments to implementation be overcome by modifying or supplementing the actions?

Differences between TSM and longer range, more expensive improvements also should be considered in setting TSM investment priorities and policies. The orientation of TSM actions toward solving near-term problems precludes a formal programming process in many cases, because officials may be under pressure to quickly implement actions once they have been designed. In addition, because TSM projects are implemented for a variety of reasons, many of their objectives may be difficult to quantify or compare. The types of cost commitments (e.g., "up-front" versus recurring) incurred as a result of programming TSM actions also can vary considerably. A traffic engineering project, for example, may have a significant construction cost partially funded by outside sources, and require only minor maintenance over a 5- to 10-year period; in contrast, a carpool matching project entails a commitment of relatively uniform funding over that same period for operations and promotion, and may have to be totally funded from local sources. With some actions, the planning costs may be a significant portion of initial implementation costs, so the decision to start a study is in itself a major programming decision. The usual approach of developing programs along modal lines in response to the priorities of and funds available to individual implementing agencies, of course, often impedes the coordination required for solving many corridor, subarea, or region-wide problems (e.g., coordinated traffic engineering, parking policy, and transit actions to solve a congestion problem). And even with this attempt to simplify the problem, agencies with restricted budgets still are left

Table 1. Key differences between TSM and long-range planning.

	TSM	Long-Range
Problems	Clearly defined, observable	Dependent on growth scenarios and projected travel
Scale	Usually local, subarea or corridor	Usually corridor or regional
Objectives	Problem-related	Broad, policy-related
Options	Few specific actions	Several modal, network, and alignment alternatives
Analysis Procedures	Usually analogy or simple operational relationships	Based on trip and network models
Response Time	Quick response is essential	Not critical
Product	Design for implementation	Preferred alternative for further study or detailed design

with lengthy lists of projects from which only a few can be selected for near-term implementation.

The approach recommended to TSM improves the coordination of planning and programming decisions so that both can be made efficiently and effectively. This is accomplished by broadening the concept of programming into strategic management, in which policy and programming questions (e.g., what problems to resolve? and how much to spend?) are addressed, in contrast to project or tactical planning, which is primarily concerned with answering design or specification questions (e.g., what actions will help solve a specific problem? and how should they be designed and implemented?). Key features of this process are:

- A consistent assessment of problems and an understanding of their causes.
- The establishment of realistic objectives for TSM actions designed to solve the problems.
- The setting of fiscal and other guidelines for design and development of actions.
- The identification of potential actions that are appropriate and feasible in the problems' setting.
- The systematic design of implementable projects that combine or "package" actions as necessary to meet the objectives established for problem solution.

The remainder of Part I covers in detail the approach recommended for planning and programming TSM actions. Chapter Two describes the overall approach and strategic management activities, such as needs assessments and capital budgeting, that provide a framework for efficient project planning. Chapter Three describes tactical or project planning activities required to develop effective solutions. The use of the manual in project planning is illustrated in Chapter Four, which serves as an introduction to Parts II (a Reference Handbook) and III (Applications).

KEY TERMS

Some of the terms used in this manual may need clarification; the following is a brief glossary:

action: either a type of physical or operational change (e.g., "reversible lanes" or "employer vanpool program") or a specific change (e.g., ban parking along Main Street between Spruce and Elm from 7 to 9 AM). In general, the implied level of detail increases as planning progresses.

package: a group of actions, either general or specific, proposed to solve a specific set of problems.

program: a list of specific actions and packages to be implemented during the next fiscal period(s), usually 1 or 2 years, supplemented with funding and scheduling information.

project or tactical planning: activities that develop detailed solutions to a specific set of problems.

strategic management: activities that establish an agency's, community's or region's needs, objectives, priorities, and improvement programs.

strategy: a general approach that can be taken to solving specific problems (e.g., "improve traffic flow" or "encourage ridesharing").

CHAPTER TWO

A STRATEGIC MANAGEMENT FRAMEWORK FOR TSM

Strategic management is a set of activities undertaken to provide an efficient, problem-oriented framework for planning, designing, evaluating, and implementing low-cost TSM projects. It covers not only the programming of recommended projects, but also the setting of realistic guidelines for design and development so projects can be funded and implemented without excessive delays. A careful assessment of needs in relation to available funding, a key aspect of strategic management, helps an agency to sort out problems that should and can receive immediate attention, and to set reasonable expectations for the performance of solutions to those problems. Even rough guidelines for problem identification and solution design can direct an agency's planning and design efforts toward developing useful and implementable actions -- the basic purpose of TSM; they also help (1) to ensure that limited funds are spent effectively and equitably, and (2) to demonstrate consistency and equity to elected officials and the general public.

The recommended framework is shown schematically in Figure 1. It draws on traditional planning, programming, and policy-setting mechanisms employed by transportation agencies and their elected or appointed overseers. The major difference is a change of emphasis, with more effort being spent on the coordinated assessment of problems and fiscal

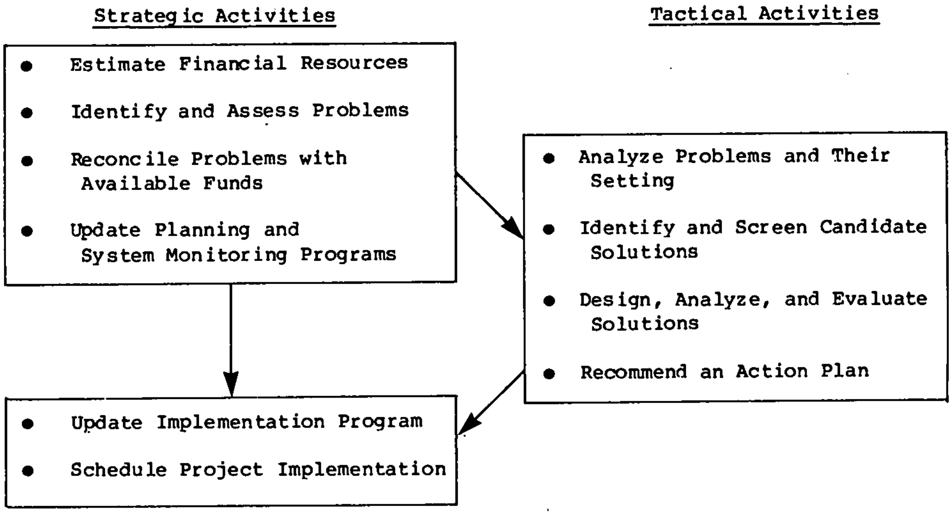

Figure 1. TSM improvement planning and programming process.

resources, and less on matching designed projects with allocated funds. In the framework, programming is not treated as an appendage to project planning and design; rather, limitations in funding and other key programming considerations (such as equity and cost-effectiveness) are addressed in several management and planning activities, and programming decisions are made as early as possible. The framework clearly separates activities that involve the development of a specific project (tactical) from those that involve the management of an agency's resources (strategic).

In applying the framework, an agency should periodically review its backlog of identified problems and improvement proposals and its (anticipated) planning and implementation budgets. Based on the review, standards and policy guidelines should be revised for assessing the presence and severity of problems and for designing and implementing TSM actions to resolve the problems. The review also can be used for a preliminary allocation of funds among categories of problems to provide working budgets for engineers and planners charged with designing solutions. The standards should not be set with the idea of restricting needs identification, for such identification is necessary to obtain a complete assessment of overall funding requirements. The purpose is to place current program development within the confines of near-term resources. While projects can still be designed to meet general, good-practice standards, initial stages designed under the strategic standards may be necessary to ensure that some immediate action can be taken to address the more serious problems.

Once standards and guidelines have been set that match anticipated funds, tactical or project-level planning can be carried out (on a local site, corridor, or subarea basis) to solve addressable problems with the expectation that solutions can be funded and implemented. Many smaller scale programming decisions can be made by project engineers in the course of developing packages of TSM actions; only a few projects may have to undergo a formal priority programming and approval process.

STRATEGIC MANAGEMENT ACTIVITIES

Strategic management is carried out by all types of transportation agencies as part of their internal planning, budgeting, and management. In short-range planning, line agencies (such as city traffic and parking departments and transit authorities) typically conduct all six activities shown in Figure 1 within their operational jurisdictions. MPO's and state DOT offices often provide necessary coordination and technical support, and may take the lead in developing and updating programs. Although procedures currently used by an agency may be adequate for carrying out its responsibilities, changes in some areas may be desirable to improve the efficiency with which low-cost improvements are planned and programmed.

Each of the strategic planning activities shown in Figure 1 is described briefly below. The descriptions are not intended to be comprehensive, and are not presented as a rigid series of steps which must be followed. Instead, they present key features that should be incorporated in the procedures used by an agency to carry out its near-term planning and management responsibilities.

Estimate Financial Resources

Funds available to a transportation agency for planning, implementing and operating low-cost improvements primarily come from the following sources:

- User fees collected by the agency, including fares, tolls, parking charges, fuel taxes, and vehicle registration fees.
- Programmed funds from federal and state agencies, which may be earmarked for specific modes or uses such as transit capital expenses or highway safety improvements.
- General and miscellaneous funds allocated to the agency from state or local sales, property, income, or other tax receipts.

Estimating the funds likely to be available from these diverse sources over the coming 2 to 6 years is an important part of an agency's short-range strategic planning.

Simplified procedures have been developed for estimating revenues and other funding sources. NCHRP Synthesis 72 (1) discusses some of the revenue forecasting techniques used by state DOT's, and provides references to descriptions and examples of their use. In addition, the Federal Highway Administration's Program Management Division has produced a series of papers on financial planning and revenue forecasting for Statewide Financial Planning Seminars sponsored by that agency. Any agency not forecasting available funds should revise these sources for applicable techniques.

In many situations, a single trend line forecast will be sufficient for estimating user fees and funds that are distributed by formula. If user fee or fare policy changes are proposed, however, an analysis of travel volume and revenue impacts usually is desirable. The Impact Estimation and Analysis Aids in the Reference Handbook recommend techniques for estimating those impacts.

An important issue in financial planning, even in the short term, is the uncertainty that must be placed on estimated funding levels from all sources due to inflation and other factors beyond an agency's control. To deal with uncertainty in its fiscal planning, an agency should make pessimistic and optimistic forecasts in addition to estimating a most likely funding level. The lower forecast provides a baseline to ensure that all critical problems receive some attention, while the higher level indicates the amount of extra tactical planning warranted to ready contingency projects for implementation if available funding exceeds expectations.

Identify and Assess Problems

Problem Sources. Problems are identified or presented to transportation agencies from a variety of sources. Some are identified in a controlled manner through monitoring and observation conducted by an agency; others are identified by outside sources. Principal sources of problems commonly solved using TSM are:

- Field Reconnaissance -- Field inspections of traffic and transit operating conditions often will identify local problems such as peak-hour traffic congestion and queues, traffic penetration of residential neighborhoods, illegal parking practices, pedestrian-car conflicts, goods loading problems, and overloaded transit service.
- Transportation Performance Analysis -- Performance data such as traffic volumes, travel times and delays; transit patronage, running times and load factors; and parking accumulation, turnover, and duration often are routinely collected by operating agencies as part of system monitoring activities.
- Requests and Complaints -- Complaints received directly from the public, through the media, or from elected officials are valuable in identifying problems. Requests from staff, other public agencies, elected officials and developers also may identify problems with existing operations, but more frequently ask an agency to examine ways of handling emergencies or major events, of allowing land development to occur without disrupting the transportation system (such requests are often part of a permit approval process), of making system improvements that reduce user and operating costs, or of taking advantage of funding programs.
- Financial Analysis -- Problems in the management of public transport and parking systems can be determined from cost-revenue analysis; problems include inadequate pricing, excessive or redundant services, excessive operating, maintenance, or administrative costs, and low productivity.
- Policy Objectives -- Problems sometimes can be identified where particular services or conditions in areas or communities do not meet broad policy objectives adopted at some level of government. Air quality, energy conservation, carpooling promotion, and mobility for the elderly and handicapped are examples of national policies that may be augmented by state and regional directives; transit coverage and revenue/cost ratios are examples of regional (or state) policy objectives.
- New Facility Planning -- Planning and design activities for new transportation facilities often forecast changes in travel volumes on existing facilities and

services in the affected corridor or subarea, or indicate places where service quality or capacity improvements are desirable to support the proposed facility.

Problem Assessment. A strategic review and assessment can help sort out "problems" identified by these viewed sources and determine which need immediate attention. Many problems identified through reconnaissance, monitoring, complaints, and requests can be reviewed and assessed at set intervals (e.g., quarterly or semiannually), and handled as part of a regular system evaluation process. Some of these may be straightforward to assess, and have commonly applied solutions that can be designed and implemented independently of other problems and agencies. Other problems, particularly those involving an executive or legislative mandate or extensive interagency coordination to resolve, may require special study. Some problems may be well defined or quantified, while others may be expressed as more general concerns even where viewed as major problems (e.g., truck traffic on residential streets).

The task of sorting out and assessing problems so they can be addressed in an efficient manner is not an easy one. A number of questions should be answered as part of this process, including:

- Is the perceived problem a real one? Or does it represent a data error or an infrequent event?
- Does the problem require immediate attention? Or can it be deferred for at least a few years?
- Is the problem strategic in that it adversely affects basic transportation services (e.g., a major bottleneck on an approach to the CBD)?
- Can low-cost TSM actions be implemented to solve the problem? Or are capital-intensive improvements needed?
- What is the approximate cost of resolving or alleviating the problem?
- What funds are available to finance the implementation and operation of problem solutions?
- What agencies must be involved in developing and implementing solutions for the problem?

A checklist of questions directly related to an agency's responsibilities can be a useful aid in sorting out problems.

Field reconnaissance and performance analysis, two of the problem sources noted above, also can help answer some of these questions. To simplify those activities, many transportation agencies have devised worksheets for recording and appraising physical and operational conditions on the facilities and services they operate, and use this information both to identify and assess problems. Depending on the agency's responsibilities, an assessment normally should include:

- Geometric and alignment characteristics (e.g., pavement width, lane width, and horizontal and vertical curvature).
- Physical condition (e.g., damage and wear on structures, roadbed, pavement and curbs).
- Signing (e.g., signal and sign design and placement, and striping design and condition).
- Safety (e.g., accidents and accident rates, presence and condition of warning devices, guardrails or other protection).
- Service quality (e.g., operating speeds, delays, volume/capacity ratios, schedule adherence and coverage).
- Productivity (e.g., passenger-miles or passengers boarded per vehicle-mile, per vehicle-hour or per driver-hour).
- Cost recovery (e.g., percentage of operating costs covered by farebox revenues).

In many cases, ratings or scores can be assigned to specific facilities or services and compared to standards or criteria to measure the severity of a problem. Notes on Evaluation and Packaging Techniques in the Reference Handbook discuss some of the problem assessment procedures (often referred to as deficiency or sufficiency evaluations) that currently are used by transportation agencies.

The periodic monitoring and systematic appraisal of transportation facilities and services are very important parts of strategic management, because these activities provide an agency with information necessary to carry out its responsibilities as the manager of a public investment. A performance analysis should be part of this process, but it need not be a detailed or elaborate rating scheme. For example, consistent criteria that can be applied to distinguish categories of problems such as "critical," "severe," "moderate," and "slight" are sufficient for most agencies. Critical problems, for example, might include:

- Structural or physical conditions that restrict the use of a bridge or highway segment.
- A high frequency of transit vehicle breakdowns that hamper the provision of basic services.
- Signal systems that frequently malfunction and hinder smooth and safe operations.
- Air pollution "hot spots" far in excess of standards.
- On-street parking that interferes with traffic flow and transit operations.

The assessment should produce a fair and realistic portrayal of problems and their relative importance. Sometimes observation will suffice; sometimes data collection and analysis will be needed. Checklists and simple worksheets should be used whenever possible to prepare and present information and appraisals. Problem assessment, however, should not become so complex that it precludes timely decisions and prompt actions.

Reconcile Problems With Available Funds

The performance standards an agency uses to identify and assess problems should reflect the local operating environment and financial resources available for their resolution. If standards are set too high, several years worth of expected funding will be required to address an agency's current list of "critical" and "severe" problems, and the list will lengthen if new problems arise and current "moderate" and "slight" problems worsen at a faster rate than solutions can be funded and implemented. The use of "level-of-service C" or "seats for all transit riders" to identify severe peak-period problems in radial corridors of large cities, for example, would produce chronic backlogs of unattended problems. In contrast, a realistic setting of standards should produce a list of problems that can largely be resolved using anticipated funds, with almost all severe or nondeferable situations addressed over a reasonable period (e.g., 2 to 6 years depending on the size of the current backlog).

Guidelines or standards used in designing and evaluating problem solutions also should be reviewed as part of strategic management. Although standards based largely on accepted highway and transit design and operations practice (or on local, state, and national policy objectives) may provide good measures of an agency's long-term "needs" and set an upper bound on its potential improvement budget, these standards usually provide poor guidance for near-term systems management. The use of high standards in designing improvements often produces a "wishlist" of projects that exceeds available funds and allows only the most critical problems to be solved. An adjustment of design guidelines may enable an agency to resolve or alleviate more of its problems, and generally results in a more beneficial or cost-effective investment of limited funds. The use of 10-foot turn or travel lanes on urban arteries, for example, may allow operational and capacity improvements to be made at many problem sites where the expense of widening to comply with a 12-foot standard would preclude an improvement.

Transportation agencies in several states have developed or applied procedures that extend the concept of a traditional needs analysis to consider funding limitations, primarily in response to declining funds for statewide highway construction, reconstruction, resurfacing, and maintenance (1, 2). In some cases, impact estimation techniques (such as speed/flow curves) have been used in conjunction with benefit/cost or cost-effectiveness analysis to examine the implications of different performance and design standards. A study of proposed major highway improvement projects in Wisconsin (1, 3) showed that lower cost improvements (e.g., widenings, spot improvements, 2-lane freeways, and bypasses) were more cost-effective solutions in many urban and rural corridors than the 4- and 6-lane freeways initially proposed using previous design policies. The inclusion of the lower cost alternatives in a recommended 6-year program increased the overall program benefits and allowed most of the identified capacity and service quality problems to be addressed. In effect, state policy was revised to favor solutions that (1) solved near-term capacity and service-level deficencies, and (2) were in line with limited construction budgets. TSM itself represents a similar response to fiscal, effectiveness and equity concerns, because its low-cost actions allow a community to respond to several problems instead of concentrating limited funds on solutions to a few.

The adjustment of standards and guidelines to reflect funding levels does not have to be a complex process. Agencies with jurisdiction over only a few types of facilities or services will need few indicators to assess their performance. Even large agencies, once they have examined the cost implications of current standards and established more realistic guidelines, should find periodic review and adjustment a simple process. What is needed is only a few, simple performance guidelines that:

- Provide a reasonably consistent basis for judging deficiencies, and clearly distinguish critical, nondeferable needs from less severe problems.
- Allow planners and engineers to design solutions that can be implemented with available funds.

The guidelines and standards should remain consistent over a 3- to 6-year period, and not fluctuate in response to changes in annual budgets and in the number of problems "arising" each year. This implies that anticipated problems and budgets need to be smoothed over time, so that an agency is truly thinking in terms of managing a resource. While the complexity of funding sources, limitations placed on their use, and changes in their annual budgets will often require the rescheduling of actions, realistic performance standards will provide a benchmark that is sufficiently accurate for "programming" problems assessed either on a case-by-case basis or as part of an agency's periodic review of its domain.

Update Planning and System Monitoring Programs

Project planning must be carefully scoped if problems designated for early solution are to be efficiently and effectively resolved. Questions that should be raised and at least partially answered at this point include:

- Can a detected problem be treated in isolation, or is it better addressed in combination with other related problems identified in the same vicinity or along the same travel corridor? (For example, intersection delay and accident problems along an artery might best be solved with a package that includes signal coordination along the artery.)

- Are there problems expected to occur in near future that might be efficiently addressed along with more immediate problems? (For example, improvements to an artery might allow for travel in the parking lanes, reversible lanes, and/or additional access points once adjacent sites are redeveloped.)
- Is the solution of a given problem likely to introduce new problems or shift problems to nearby areas? (For example, closing a street to create a pedestrian mall may create traffic congestion on adjacent streets if bypass routes are not planned.)
- Is a detected problem a symptom of a more fundamental problem? (For example, increased crosstown travel that creates traffic congestion on radial segments where dog-leg movements are necessary.)
- Are special data collection or analysis efforts required to resolve a problem? And, if so, how can the data collection be tailored to staff and funding resources?

Although detailed answers to many of these questions may have to be deferred until project or tactical planning (discussed in Chapter Three) is under way and additional data have been assembled, available information usually can be used to organize an efficient project planning work program. This program defines the scope of each project planning study, and should include the following types of information:

- Boundaries of the study area.
- Problems to be addressed or objectives to be accomplished, with an indication of priorities.
- Indication of solution approaches to examine.
- Issues to consider in designing and evaluating solutions.
- Guidance on funding available for implementation and operation.

As part of this program, interrelated or contiguous problems should be considered together in corridor and subarea studies, and interagency task forces should be organized where appropriate to conduct, coordinate, or oversee these studies. In addition, system monitoring programs might be revised to collect any new data required for the planning studies, and to intensely monitor facilities and services where problems appear to be developing or worsening. Manuals developed by USDOT and other agencies provide guidance on the types and amount of data required in different situations (4, 5).

Update an Implementation Program

Once the planning of a project has been completed (using the 4-phase process described in Chapter Three), an agency may (1) immediately commit funds for implementing the recommended actions, (2) defer a decision until funds are available or an annual or other periodic programming meeting is convened, or (3) resubmit the problem for further analysis with revised guidelines for developing solutions. The first option clearly is preferred in TSM, given its quick-response objective. Strategic management promotes the use of that option, because agency officials often will know from previous budget and standard reviews if a package of TSM actions can be programmed and implemented immediately without jeopardizing the implementation of solutions to more severe problems.

In general, project packages committed to implementation at completion of design should have several of the following characteristics:

- Be designed to solve one or more severe or critical problems.
- Consist of actions that are proven to the point where officials are confident of their estimated costs and their effectiveness in solving the identified problems.
- Have low costs or be almost financially self-supporting.
- Use special funding sources, or draw on sources with ample funds.
- Have design specifications that do not depend on other planned or committed projects.

A more difficult programming task is to allocate uncommitted funds among projects competing for their use, i.e., to select project packages not yet committed to implementation for inclusion in a 1-, 2- or 3-year improvement program. Techniques have been developed to assist in this task, and some are described in the Notes on Evaluation and Packaging Techniques in the Reference Handbook. Although some of these techniques (e.g., benefit/cost of cost-effectiveness) can be useful in examining some trade-offs involved in programming decisions, none is well suited for rigorous application to the diversity of problems and actions covered by TSM, or to the small scale of most projects.

Informal approaches that are suitable for packaging actions or setting priorities in a project analysis also are of limited use. For example, a simple rule such as "improve the arterial street system first" might work as a guide for staging roadway improvement in a corridor study, but does not work in developing a community or regional program if complex trade-offs involving different modes and objectives are involved.

Issues that may complicate the development of a short-range improvement program include:

- Allocating matching funds for different federal and state programs (e.g., transit capital grants vs. federal aid to urban systems).
- Providing for private investment in the community (e.g., improving access to a proposed office park).
- Responding to citizen concerns (e.g., reducing traffic on residential streets).

- Equitably distributing improvements (e.g., funding small improvements in several parts of the community vs. concentrating on a computerized traffic signal system in the downtown).

The best approach appears to be the application of an iterative process that begins with sorting unfunded project packages into a few categories of priority largely based on the severity of the problems they solve, the number of people they benefit, and the costs of their implementation and operation. The agency would then assign funds to each category, starting with the highest priority, until all budgets were exhausted. After funding each category, officials should step back and examine the program as a whole to see if it meets other objectives of the agency or region (for example, an equitable geographic distribution of projects), and move packages into or out of the program as required to meet these objectives. Such a filtering scheme is used by the Toronto Transit Commission in selecting bus route changes (6).

In applying the process, alternative or optional packages should be considered for some project study areas. For example, intersection realignments designed to solve safety problems along an arterial corridor might form a basic package for that site, and be assigned to a high priority category for programming. Other recommended improvements to the corridor, such as signal coordination to improve traffic flow, could form supplementary or "second-stage" packages and be assigned to lower priority categories that might be deferred for a few years. Project planning activities, discussed in Chapter Three, should allow for this flexibility by developing realistic staging sequences.

Projects previously programmed but not yet implemented also should be reviewed, because some might be displaced by higher priority projects that have been planned since the last program update.

The objective of this activity should be a list of project packages to be implemented in the next 1 to 3 years matched with allocated or anticipated funds. The program also should list some contingency projects that can be readied for implementation if supplementary funds become available or if problems arise that cancel or defer programmed packages. In effect, proposed projects are separated into three categories:

1. Implement unless funding or other problems develop.
2. Implement if supplementary budgets are approved.
3. Defer to later programming periods.

There is no need to rank projects as a whole or within each category, and the limited accuracy of most cost and effectiveness estimates will not support a detailed ranking.

Schedule Project Implementation

The actual scheduling of programmed packages may be performed in conjunction with program development or as a separate step. The schedule will depend on several factors, including:

- The availability of funds for their implementation.
- An agency's contract procurement procedures.
- The need for detailed engineering or environmental impact studies.
- Review and approval procedures required by funding sources.
- Coordination with system operating procedures, such as bus route scheduling and run cutting.
- The availability of staff to supervise or conduct the implementation.

Although scheduling techniques, such as PERT or CPM networks, are used at some state DOT's, an informal or manual procedure is adequate for transportation agencies in most cities.

SUMMARY OF FRAMEWORK FEATURES

Strategic management draws on procedures used both in the public and private sector to control and monitor limited resources. It is not a rigid process, but one that can be adapted to the needs and responsibilities of individual agencies. It is well suited to TSM, for it enables investment and operational decisions to be made on an on-going basis so an agency can respond quickly to problems. It is directed toward project design and implementation, not toward proposals, plans, and reports.

Standards and guidelines set for assessing problems and designing solutions are key to strategic management. They allow funding limitations to be considered early, and enable an agency to quickly determine which problems can be addressed right away and which must be deferred. They provide an agency with the means to maintain consistency among the problems addressed and the projects designed and implemented for their resolution. In effect, strategic management enables short-range planning and project development to be undertaken in an efficient, uniform manner related to critical needs and available resources, while remaining consistent with broader systems operation, mobility, and other objectives.

The absence of formal techniques in the recommended framework should not be regarded as a weakness, or as an argument for arbitrary or subjective decision-making. On the contrary, the framework encourages a series of objective decisions that can be presented clearly and succinctly to elected officials and the public, specifically:

- What are our critical problems?
- How were they determined to be critical?
- What funds are available for their correction?
- How should the funds be spent?

These decisions can be documented in annual reports, service and design warrants, problem assessment sheets, project summary sheets, and program implementation schedules.

An important feature of the framework is that it helps reduce effort wasted in planning projects and designs that cannot be funded and implemented. Conversely, the detailed designs needed for implementing solutions to "programmed" problems can be developed in a pragmatic and efficient manner knowing that they will not become obsolete before implementation because of changes in travel patterns, costs, or funding availability. Interagency cooperation fostered during planning and design can be continued directly into implementation and operation, and not dissipate as a result of changes in agency personnel or priorities while package components await funding.

As an illustration of its application, the Pennsylvania Department of Transportation recently initiated a special program to make better use of federal highway funds (7). The program was targeted at low-cost highway projects that reduced congestion delays, accidents, and energy consumption. After experiencing difficulties in selecting projects submitted by county agencies, state officials took the following actions:

- Developed checklists of questions to help sort out problems and screen actions.
- Established funding guidelines for different types of corridors.
- Established evaluation criteria (e.g., a minimum benefit-cost ratio, a minimum federal participation rate, and a minimum daily traffic level) that would apply to all projects.
- Distributed a set of standard techniques for estimating the corresponding evaluation measures.

As a result, their programming task was simplified to the selection of the best 50 percent of submitted projects from the selection of the best 5 percent a year earlier.

CHAPTER THREE

PLANNING TSM PROJECTS WITHIN THE FRAMEWORK

Strategic management activities set up a policy framework in which low-cost projects can be efficiently planned and implemented. They provide the planner or engineer with sufficient information and guidance to allow project planning to be conducted as an engineering, operations or design effort. They identify:

- The problems to be addressed.
- The resources available for implementing solutions (e.g., approximate level of available funds and any restrictions on their use).
- Guidelines and standards to apply in designing and evaluating solutions, including any secondary impacts that should be considered.

This chapter shows how individual TSM projects can be efficiently planned within the strategic framework. The first section describes a 4-phase tactical planning process that leads to a recommended design ready for implementation. The second section discusses issues in the analysis and evaluation of projects that should be considered throughout the four phases.

TACTICAL PLANNING--A 4-PHASE PROCESS

With the establishment of realistic strategic guidelines, project or "tactical" planning activities can be conducted in a 4-phase process that culminates in TSM actions that are ready for implementation. This process is shown schematically in Figure 2. It involves a sequence of increasingly detailed decisions that lead to a workable solution. The key to this process is simplicity; an analyst is never required to seek or estimate information more precise or complex than is necessary for the immediate decision. It can be carried out by traffic engineers, transit service planners, or transportation planners working individually or together to solve a variety of near-term problems.

The TSM project planning phases shown in Figure 2 are described in the following in terms of a corridor or subarea study undertaken to solve several problems; their application to an isolated problem would be much simpler. For example, a study of accident records (in Phase 1) might indicate that conflicts during left-turns are the cause of an intersection accident problem. In that case, Phases 2

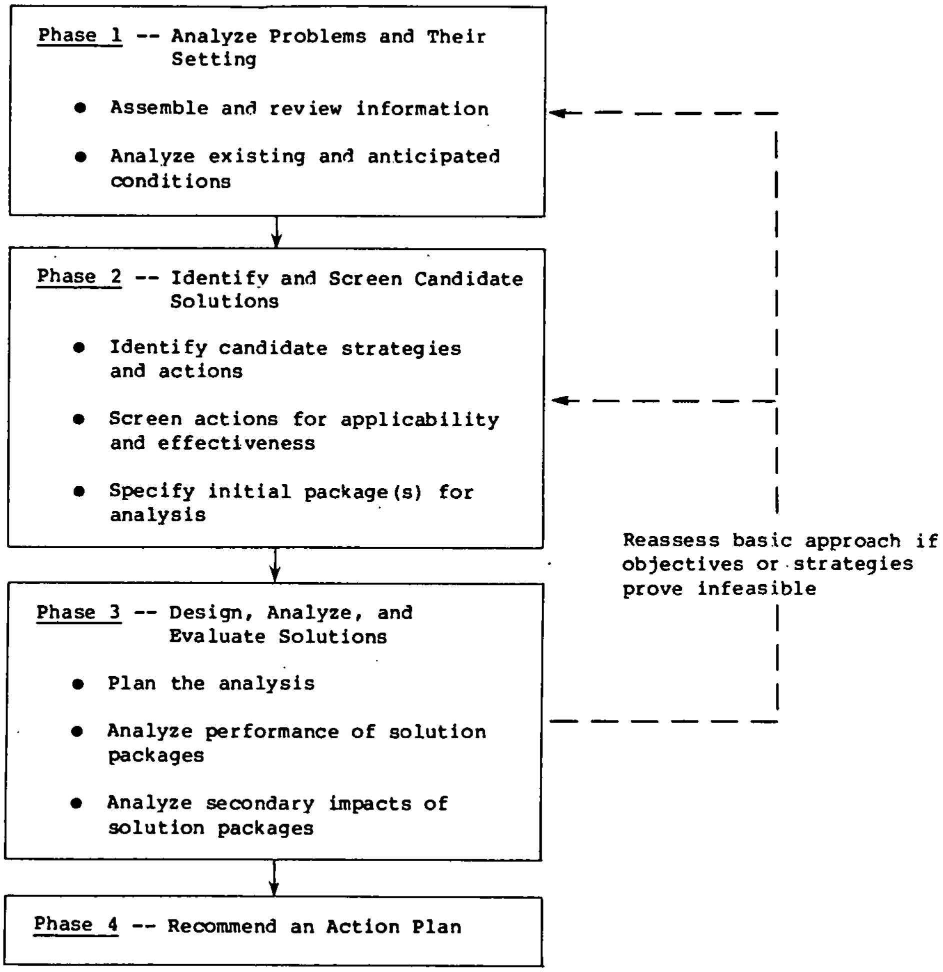

Figure 2. Project planning phases.

and 3 might be limited to a physical and operational assessment of left-turn lanes and signal phases.

Example case studies in Chapter Four and Part III of this manual show similar adaptations of the process in a variety of settings. The following discussion should not be viewed as a rigid process, but as a process that can be simplified or changed to meet the needs of specific applications.

Phase 1 — Analyze Problems and Their Setting

A thorough "conditions analysis" conducted early in project planning can provide information needed to identify and develop effective solutions. Even where the "problems" are related to proposed development or nontransportation concerns such as urban vitality, the knowledge gained from a conditions analysis will assist in the identification both of opportunities for improvement and of clear and realistic objectives to guide project design.

1a. *Assemble and review information.* Problem identification and assessment conducted as part of strategic management will provide some information on the problems and their causes, but it may not be sufficiently detailed for project analysis and design. More information may be needed to determine the underlying deficiencies in the transportation system that cause or contribute to the perceived "problems"; otherwise, an analyst may be dealing only with a few symptoms. Information on the problems' setting, including any development plans and short-term travel forecasts, should be assembled and reviewed to identify opportunities for action, constraints that may affect the feasibility or design of solutions, and travel that should be accommodated by any proposed actions. Anticipated land use and travel changes also may lead to problems on other facilities in the immediate area, and their resolution in conjunction with immediate problems often will be cost-effective. A conditions analysis also may have to extend beyond the immediate problem area; for example, congestion on an arterial may be caused by drivers bypassing expressway congestion, and thus must be viewed as a corridor problem.

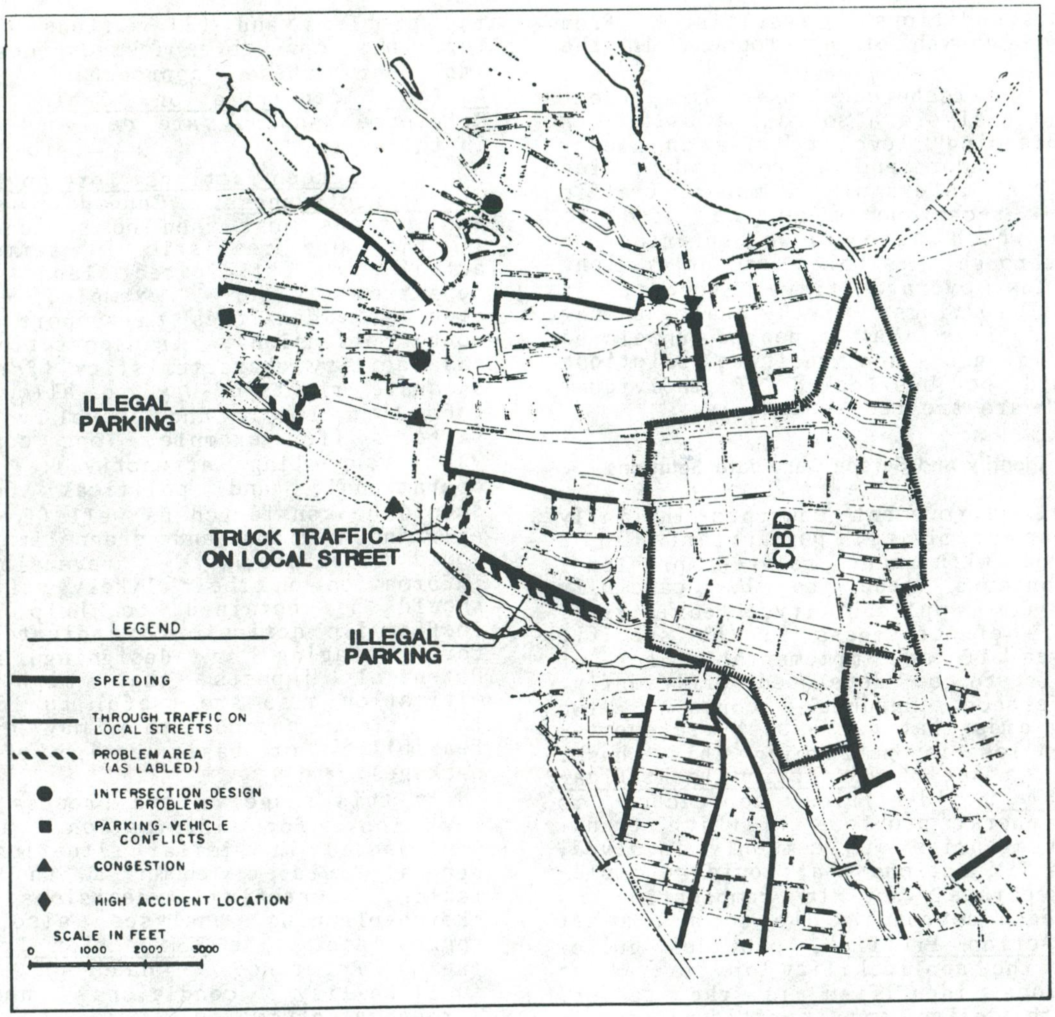

Figure 3. A sample problem map. Source: Reference 9

A useful way of addressing many of these issues is to graphically illustrate information related to the problems and their setting. A simple display of problems on corridor or community base maps often can show relationships among the measured or perceived problems, highlight underlying causes, and lead to coordinated solutions. An example of a problem map is shown in Figure 3.

In addition to "mapping" problems, plots of traffic volumes, travel times, queue lengths, transit loads, and other performance measures can help agency officials and others understand how well or poorly existing transport facilities and services operate, and provide a benchmark for assessing the effectiveness of proposed solutions The plots also indicate where information is lacking, and may need to be supplemented by field surveys or counts.

If additional data collection appears warranted, the analyst should make a quick pass through subsequent planning steps; specifically, he should:

- Anticipate results of survey or counts.
- Identify and screen solutions that would be indicated by the expected results.
- Draft an analysis plan for designing and evaluating the solutions.

This exercise will indicate if the data collection is necesary, identify the key information that should be collected, and aid in the preparation of an efficient collection effort.

1b. Analyze existing and anticipated conditions. A field reconnaisance often will help an agency understand the operation of existing facilities and the causes of identified problems. Analyses of accident reports, traffic or rider counts, and other information also is useful. Techniques described in the Impact Estimation and Analysis Aids in the Reference Handbook can be used to estimate capacities and other performance mesaures that are difficult to measure directly. The aids also cover travel forecasting and other techniques that can be applied to analyze conditions resulting from anticipated growth or development in the study area.

Estimation techniques used in project design and analysis also can be used at a "sketch planning" level to give an agency a better understanding of identified problems. As an example, a manual traffic assignment technique might be used to determine which trip flows entering or passing through a subarea encounter long delays, low average travel speeds, or circuitous routings. Such analysis may connect problems that appeared unrelated at first glance, and indicate solutions that would be overlooked if individual "problems" are treated separately.

Phase 2 -- Identify and Screen Candidate Solutions

Several improvement concepts initially may appear promising, particularly in a study area with many related problems. These concepts need to be carefully screened for applicability, feasibility, and likely effectiveness in the specific study area if an implementable set of actions is to be developed efficiently. The Reference Handbook contains two screening aids that can assist transportation agencies in performing this phase. The first, a set of TSM Action Identification Tables, identifies approaches to solving general problems in which transportation agencies are commonly involved, and lists TSM actions that could be implemented separately or in combination as part of each approach. The second, a set of TSM Action Profiles, provides guidelines on the applicability of several of the actions identified in the tables, along with design and operational considerations and other information useful in their screening. An agency's service, design, or operational warrants also should be applied in conducting this phase, and any previous analyses of similar problems should be reviewed.

The three steps in identifying and screening are as follows.

2a. Identify candidate strategies and actions. Once the problem is clearly defined, the analyst should look for general approaches and strategies to pursue in developing solutions (such as "improve traffic flow" or "encourage transit use"), as well as specific types of actions that might be implemented as part of these strategies (such as signal improvements or increased bus frequency). The scales of action (e.g., implementation within an employment center versus along approach corridors) also must be considered so other agencies and actors can be brought into the planning process. In effect, an analyst needs to step back from the results of the problem analysis and broadly consider potential courses of action that might be relevant to his specific problems, objectives, and setting. These may include transit actions to help solve traffic problems and operational actions to help solve capacity problems. This step should produce (1) some basic, feasible approaches to solving the problems and (2) actions that might form the core of packages designed to implement these approaches. The TSM Action Identification Tables in the Reference Handbook are designed to assist in this step.

2b. Screen actions for applicability and effectiveness. Candidate strategies and actions must then be screened to see if they are realistic in terms of the actual or anticipated land uses and densities (for example, adequate population densities to support a transit route extension), transportation system and facility characteristics (for example, adequate rights-of-way to allow a 2-way left turn lane), and travel volumes and patterns (for example, long commutes to make vanpooling attractive). Physical, operational, and political feasibility should be considered as well (for example, existing medians and channelization that would interfere with a reversible lane). Information on their likely effectiveness should be obtained to help weed out ineffective actions and indicate the need for packaging in designing solutions. Potential impacts that might require mitigation also are useful to identify at this time, because they may affect the feasibility or basic design of proposed packages.

At this stage of the process, analysts may look for information on actions implemented in similar situations or for general "rules of thumb" as the basis for making screening decisions; simple sketch-planning analyses also may be appropriate. The TSM Action Profiles in the Reference Handbook provide applicability conditions and other screening information.

2c. Specify initial package(s) for analysis. The actions that survive the screening step usually are not sufficiently detailed to permit implementation, and a starting point is needed for analysis and design. In many situations, the nature of the problems almost mandates the solutions, so a single package will suffice; in others, two or three packages representing different strategic approaches may provide a better starting point. Unlike systems planning, however, these "alternatives" will be modified, refined, discarded, or combined as necessary during the design process in Phase 3.

Phase 3 -- Design, Analyze, and Evaluate Solutions

The fleshing out and refinement of the preliminary packages to produce implementable actions entails a series of detailed decisions concerning their design and operation. All analysis should be directed at providing information for those decisions, and should be as simple as possible. The Reference Handbook contains Impact Estimation and Analysis Aids designed to help an analyst structure an efficient analysis and select appropriate estimation techniques for carrying out the analysis. Key analysis and evaluation issues are discussed later in this chapter.

The design, analysis, and evaluation of project packages is an iterative process involving the following steps.

3a. Plan the analysis. An analysis plan should be prepared that covers factors and criteria to be used in evaluating solutions; performance and impact measures and other information needed for their design and analysis; and techniques for estimating the measures. A carefully scoped plan will help avoid unnecessary and wasted effort, and ensure that the measures and information are prepared in sufficient detail for their intended use in analysis and evaluation. The plan is not rigid, and should be modified as new insights are gained in the course of the analysis. The next section of this chapter discusses key issues in preparing an analysis plan and presents an example. The TSM Action Profiles in the Reference Handbook list potential evaluation factors and measures for several actions, and the Impact Estimation and Analysis Aids provide detailed guidelines on selecting performance measures and estimation techniques.

3b. Analyze performance of solution packages. The initial action packages defined in Phase 2 first should be analyzed in terms of primary performance measures, i.e., those that determine the extent to which the actions solve identified problem(s) or meet design objective(s). The choice of primary measures will reflect the circumstances and actions involved, but usually involves one or more of the following categories:

- Service quality (e.g., travel time or speed).
- Capacity (e.g., vehicle and person carrying rates).
- Volumes/usage (e.g., traffic volumes, transit ridership or vehicle occupancy).
- Safety (e.g., accidents or traffic conflicts).
- Cost (e.g., capital, operating and maintenance).

Other measures, such as retail sales, aesthetics, air quality, and noise reduction also can be primary measures in situations where they are key factors in making design decisions.

The analysis should be viewed as a search for a good solution that meets financial, physical, and other constraints, not as an "alternatives analysis" where package specifications remain fixed. Consequently, actions should be modified, added, or discarded if analysis indicates that the changes would improve the performance of a package while retaining its feasibility. If the performance analysis indicates that the initial packages do not adequately solve the problems, the incremental contribution (or performance) of individual actions can be estimated and used as a basis for expanding or reducing their importance in the package. Cost-effectiveness or benefit/cost analysis can be used in comparing actions and packages; these techniques are discussed in the Notes on Evaluation and Packaging Techniques in the Reference Handbook as are other approaches that agencies have used in developing and assessing packages of TSM actions. Major or minor design modifications may be suggested by the analysis, as may the need for additional or supportive actions. If no packages appear able to solve the problems, the problems themselves may have to be reassessed or new evaluation or design criteria established.

3c. Analyze secondary impacts of solution packages. Only at this stage, after action packages have survived the tests of feasibility and effectiveness, should "secondary" issues and impacts be analyzed. Depending on the specifics of the problems and actions involved, the following issues might be examined:

- Public opinion or community acceptance.
- Institutional or legal issues.
- Social, environmental, or economic issues.

As with the primary evaluation factors, the packages should be modified as required to bring the impacts to acceptable levels. If major modifications are made, their performance should be checked to ensure that desired levels are still achieved and that the problems are still resolved.

Any interagency agreements that are required for smooth implementation and operation should be in preparation at this time to ensure that proposed packages are feasible. For example, discussions with the police department to draft an enforcement plan will indicate if adequate space has been provided for patrol cars and apprehended vehicles. The TSM Action Profiles in the Reference Handbook contain similar design and operational considerations for several actions, as well as references to reports and articles that describe operational experiences. Another NCHRP report (9) discusses the institutional issues involved in implementing various congestion-reduction measures.

Phase 4 — Recommend an Action Plan

The task of assigning priorities to short-range transportation projects is not easy. In the final analysis, this task is in the domain of elected officials and their appointed representatives. Professional transportation planners and engineers, however, have the responsibility of recommending projects and of presenting sufficient information about available alternatives to ensure that the final choices can be made on a rational and justifiable basis.

Following analysis and design, a TSM action or package for the study area should be recommended for implementation or for programing along with actions directed at other problems. The key to TSM is implementation, so the action plan should consist of an implementable "design" (e.g., detailed engineering or operational plans), not a proposal for further study. The plan also may include schedules for a staged implementation, any required review and design activities (e.g., preparation of an EIS), and recommendations for possible supportive actions by other agencies.

In many cases, a staging sequence that meets anticipated project budgets will be obvious to agency staff. In other cases, cost-effectiveness or benefit/cost analysis may be useful; these techniques are described in the Notes on Evaluation and Packaging Techniques of the Reference Handbook along with other techniques that have been used to package and stage actions.

A major part of this phase often is the presentation of recommendations to policy setting and programming officials or agencies, providing them with sufficient information to adopt the recommendation and support or justify the investment needed to implement and operate the package. Presentations to merchants and community groups also may be needed to obtain political support.

In summary, the 4-phase process provides a practical and flexible framework for developing TSM solutions. An analyst may proceed quickly through the steps in tackling a simple problem, while a complex corridor or subarea problem analysis may involve considerable iteration and refinement in Phase 3 to develop a workable and acceptable solution. The "process" is a means to this end, and any paper products are merely incidental or supporting documents.

Case studies (in Part III of this manual) illustrate the application of the 4-phase planning process in a variety of settings, while the Reference Handbook (Part II) is designed to support agencies' staff in carrying out the process. The Handbook includes:

- Tables that identify strategies and types of TSM actions to consider in developing solutions to several common problems.
- Profile sheets on selected TSM actions that note conditions under which they are applicable and effective, problems potentially encountered in their implementation and operation, performance and impact measures often considered in their analysis, and sources of detailed information on their design and performance.
- Tables that recommend estimation techniques and procedures for use in common planning and design circumstances, and cite references for more detailed descriptions and application examples.
- Notes that describe the use of selected estimation techniques that are not presented in readily available publications.
- Notes on problem assessment and packaging techniques, and on the application of cost-effectiveness and benefit/cost analysis.

The remainder of this chapter discusses key issues in the analysis and evaluation of project packages and presents an example analysis plan. Chapter Four uses a corridor study to illustrate the application of the 4-phase process and the Reference Handbook.

KEY ANALYSIS AND EVALUATION ISSUES

Analysis and evaluation may occur throughout the 4-phase project planning process previously described. For example, a conditions analysis (in Phase 1) may involve the estimation of near-term travel growth, a screening of possible actions (in Phase 2) may involve a rough estimate of their effectiveness in reducing travel delays, and the development of an implementable project (in Phase 3) may involve the estimation of travel speeds and implementation costs, and an assessment of potential safety and air quality impacts.

The approach taken in a specific analysis will depend largely on the problems and characteristics of the study area and the proposed actions. Certain aspects, however, are common to all analyses:

- The establishment of factors and criteria for judging the merits of proposed solutions and deciding on a course of action.
- The identification of performance and other impact measures that are required for assessing options and making decisions.
- The chaining of performance and impact measures for efficient estimation and assessment.

Guidelines on these aspects of analysis are presented in this section, followed by an example of their application in preparing an analysis plan for a typical subarea study. An analyst should be familiar with this material before applying the Impact Estimation and Analysis Aids contained in the Reference Handbook, because it provides guidance in limiting the amount of estimation and analysis necessary to develop workable and feasible TSM packages.

Establishing Evaluation Factors

Evaluation of existing transportation facilities and services is accomplished using factors such as safety, physical integrity, service quality, productivity or cost that are considered "important" by agency or elected officials. "Measures" of how specific facilities and services perform with respect to these factors are obtained, and compared to standards to determine if their performance is "good," "bad," "acceptable," etc. Examples of transportation standards are:

- A minimum operating speed of 25 mph on city arterials outside the CBD during peak travel periods.
- A minimum boarding rate of 20 passengers per vehicle-hour on crosstown bus routes.
- A maximum ½-mile walk to a bus stop in areas with a residential density over 4,000 people per square mile.

Factors influenced by transportation also may be considered in evaluating the system or its components; a common example is air quality, for which maximum hourly concentrations of carbon monoxide or other pollutants might be established. Often objectives associated with these "indirect" factors are vague, such as "allow for economic growth" or "maintain vitality of the central business district"; nonetheless, they represent considerations that are important and may influence the operation of the transportation system.

The evaluation of proposed actions should similarly be directed at the decisions to be made in designing and implementing solutions. Proposed solutions that are not major investments do not need tests more rigorous than those applied to existing facilities and services. In effect, performance evaluation carried out in Phase 3 of project planning should be a simulated "sufficiency" or "conditions analysis" of proposed and anticipated conditions conducted to determine the extent to which proposed actions solve problems.

In general, only a few factors are needed to assess the effectiveness of proposed actions; these are the factors that determined the existence of problems. Even where indirect factors such as air quality are primary in the evaluation, desired levels of performance often can be transformed into direct transportation criteria. Examples are flow separations required to meet safety criteria and traffic volume reductions or traffic flow improvements necessary to meet air quality criteria.

Additional criteria, however, often are required to determine if the proposed packages:

- Conform with general objectives such as fiscal responsibility, energy conservation, or safe system operations.
- Have other impacts or side effects that may thwart or impede implementation.
- Create transportation or related conditions that fail to meet established standards.
- Merit implementation before actions recommended to solve problems at other sites.

These "secondary" criteria usually can be less detailed and often are qualitative rather than numeric thresholds. Examples are:

- To keep enforcement and maintenance efforts with the capabilities of existing personnel.
- Not to degrade air quality.
- To maintain convenient routes for pedestrian access and circulation.
- To maintain access for goods delivery and emergency vehicles.

The numbers and complexity of these secondary considerations will depend on the type, severity, and extent of the specific problems; the scale and complexity of the study area; and the basic approach proposed to solve the problem.

Identifying Performance and Other Measures

Performance measures of existing and proposed operations are key to the analysis, design, and evaluation of TSM actions. Existing performance levels are used to identify and assess problems and determine the applicability of candidate solutions, while measures of anticipated performance levels (or changes from existing performance levels, i.e., impacts) are used in judging proposed solutions.

Performance measures of existing facilities and services are particularly important in short-range analysis, because much of the information on which design decisions will be based can be obtained through the observation and analysis of existing operations. Examples of performance measures are average peak speeds and segment vehicle volumes on a street segment, transit route boardings and load factors, and annual agency maintenance and operating costs. Factors influencing travel, such as land use, population, employment, and auto ownership, may be included in the base, because they determine the applicability and useful life of many actions. So too, may factors affected by transportation such as air quality and noise levels. Some data are used directly in evaluation, and others to derive or calculate evaluation factors. Most importantly, this information base provides an understanding of how a particular portion of the transportation system functions.

Values of the measures required for assessing existing conditions usually can be obtained through direct measurement, although many often can be derived or estimated to sufficient accuracy levels at far less cost. An assessment of proposed or anticipated conditions of course requires the estimation of the same measures, and these may have to be supplemented by forecasts of additional items (e.g., travel volumes) that are directly obtained for existing conditions. In making these estimations, the analyst is attempting to create a model or snapshot of anticipated operations that can be assessed in the same way as existing operations. Consequently, if a factor is only of minor importance in evaluating existing conditions, little effort should be spent in estimating measures used in the equivalent "after implementation" evaluation.

Despite the wide variety of TSM actions, applications, and impacts, most potential performance measures and other information useful for their analysis can be grouped into the following categories:

1. Capacity/Supply, or measures of the amount of transportation provided. Examples are lane-miles, maximum vehicle or person processing or carrying rates, number of parking spaces, sidewalk width, transit fleet size, and bus-miles.

2. Service Quality, or measures of the service offered to individual users or groups of users. Common examples are point-to-point travel times, door-to-door or journey times, intersection delay times, wait times, fees, fares, and "out-of-pocket" auto operating costs. The degree of safety or absence of hazards encountered in travel is another important service quality measure. The chance of getting a seat on a transit vehicle or of understanding a sign, signal, or pavement marking also can be considered service quality measures, as can aggregate accessibility and mobility measures.

3. Volume, or measures of travel or use of transportation services and facilities. These measures may be aggregate or pertain only to specific facilities, modes, routes, or times of day. Travel measures also may be segmented by trip purpose, by origin or destination, or by traveller characteristics such as income or age.

4. Financial, or measures of the direct costs and revenues of transportation facilities, services, and systems. The most common cost measures are implementation or capital costs and annual operating, maintenance, administrative, and enforcement costs. Other financial measures are subsidy levels and revenue/cost ratios.

5. Public "Cost", or measures of broad, negative consequences of travel. Amounts and rates of fossil fuel consumption, noise, and air pollutant emissions and accumulations are the most common measures associated with TSM. Acceptable levels or rates are often set for these costs, because although they can be affected by physical and operational decisions, they cannot be eliminated without severely restraining travel or significantly increasing direct system or user costs. Accidents, as opposed to safety hazards, can be considered in this category.

6. Economic Activity, or measures of land use and development. These measures cover any economic or demographic changes that proposed actions will have to accommodate to be effective, as well as any disruption or displacement anticipated as part of implementing the actions. Only rarely will the ongoing operation of a TSM action have any measurable impact on land use or economic activity.

As with evaluation factors, the choice of performance and impact measures for any specific analysis should reflect the characteristics of the problems and the proposed solutions. For example, percent of bus-miles with standees, percent of riders entering the CBD without seats, and average bus loads at a screen line all are performance measures potentially useful in assessing actions designed to alleviate bus crowding, but the choice among them depends on the specific definition and location of the problem.

Chaining Performance Measures

There are general relationships among the performance measure categories that establish the order in which measures are estimated, even though their order of application or importance in an assessment may vary. These relationships should be taken advantage of in an analysis of TSM actions, because they can greatly simplify the preparation of data used in evaluating proposed solutions.

Figure 4 shows the general relationships among the six categories of measures. The boxed section contains direct transportation measures (i.e., capacity, service quality, and use). These measures, combined with existing or forecast levels of land use, economic activity, and demographics will determine the amount of travel in a study area. Estimates of these measures must be in balance or "equilibrium" if a solution's effectiveness is to be accurately assessed. This does not mean that the three relationships shown in the figure:

- Use = f (activity, service quality)
- Service quality = f (capacity, use)
- Capacity = f (use, service quality)

all must be considered in a specific analysis -- indeed, that case is a rare exception in TSM planning. Simplifying assumptions generally can be made that limit an analysis to only one or two of these relationships. For example, in considering a local traffic congestion problem, an analyst can assume that peak period traffic volumes will not be affected by the intended service quality improvement. He may have to scale or adjust existing volumes, however, to account for growth or development anticipated in the corridor or subarea over the next 5 years. The analysis then would reduce to either (1) determining the supply characteristics or capacity required to accommodate the forecast volumes at a desired service quality or (2) determining the service quality that would result from a specific improvement in capacity or supply. Similar simplifications are valid in analyzing most corridor and subarea problems, despite their apparent complexity.

The importance of the direct measures should be fully understood. With the exception of labor or management efficiency actions specifically designed to achieve financial objectives, transportation agencies accomplish objectives by modifying capacity or service quality. People may or may not respond to these modifications by changing their travel behavior (i.e., choice of mode, route, timing, frequency, or destination). The effectiveness of an action may depend heavily on the nature of this response,

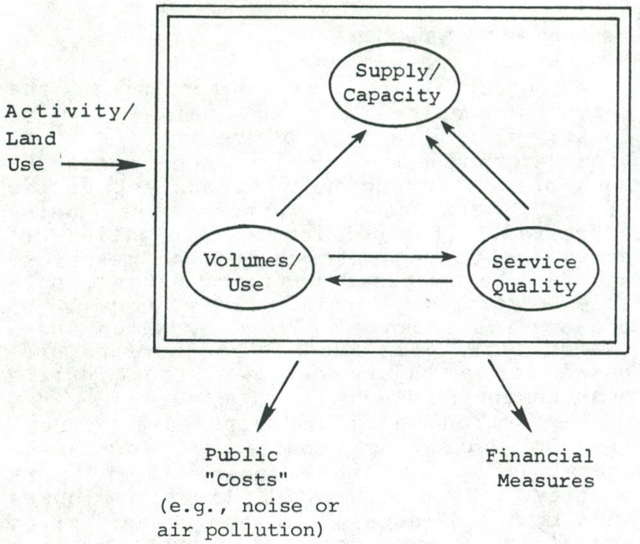

Figure 4. Basic relationship among performance measures.

whether or not it was intended or desired. Consequently, most of the estimation activity should be spent on these direct measures. Even where they are not used as primary evaluation factors, the quality of an evaluation (i.e., the confidence that is placed on the recommendations) will depend largely on the accuracy of the direct measure estimates.

The impact categories below the box in Figure 4 contain <u>derived measures</u>; i.e., the values of these measures depend on values of direct transportation measures. Some, such as accidents, air pollutant levels, and transit revenues, may be measured directly from existing operations, but this does not alter their dependence on capacity, use and/or service quality levels. They essentially mirror the quality of physical and operational services under prevailing travel patterns. In assessing proposed actions, these measures are derived from the specified or estimated values of direct measures using engineering estimates, unit rates, allocation formulas, or other simple equations or models.

A third major type of measures, not shown, consists of <u>intermeasures</u> that are developed by combining direct and/or derived measures. Intermeasures may be used in project evaluation, or to compare the relative merits of different actions being considered for an investment program. Intermeasures include productivity measures (such as passenger-miles per vehicle-hour), efficiency measures (such as bus-miles per driver-hour), and cost-effectiveness measures (such as energy or travel time savings per dollar invested). In general, they are interpretive measures that help place a scale on performance levels and impacts.

The dependence of derived and intermeasures should be fully appreciated in analyzing and developing solutions. Because reasonable estimates of these impacts can be developed quickly using values of direct measures and tables or simple equations, their estimation should be limited to specific needs for design decisions and the support of recommendations. Except where used as primary evaluation factors, these impacts rarely have to be estimated every time a proposed solution is specified or refined during the design process.

To illustrate, an engineer designing an intersection improvement to solve congestion and safety problems might sequence or chain his "estimation" activities as follows:

1. Existing peak-hour turning- and through-vehicle flow counts would be adopted (or adjusted for growth) to provide design volumes (volume/usage measures).
2. A channel/signal option, such as left-turn lanes and revised phasing, would be specified (capacity/supply measures).
3. Delay reductions would be calculated using critical lane or capacity analysis and a qualitative estimate of safety improvement would be made to determine if the option met performance objectives (service quality measures).
4. Once an acceptable design was developed, engineering estimates of constuction and annual operating costs would be made to determine if the solution met funding guidelines (financial measures).
5. If needed for program development or to "sell" the recommended solution, approximate estimates of annual accident cost savings, emission reductions and energy savings could be derived using simple equations and look-up tables (public cost measures), and/ or various "benefits" could be compared with annualized costs to measure the action's cost-effectiveness (intermeasures).

This simple illustration shows how performance and other information is efficiently prepared for use in making and supporting decisions. The same principles apply in more complex analyses.

In practice, however, an analyst may be tempted to extend or embellish the "chain" and generate information that is not required for assessment or is of questionable significance. Impacts or changes in performance produced by individual TSM actions typically are small or limited to specific groups of users (e.g., riders on a few bus routes or drivers traversing a few road segments during peak periods). These changes may be difficult to detect after a project is implemented, because they are likely to be small relative to sampling and collection errors and to growth and other unrelated events. Changes in factors normally measured at a more aggregate level (e.g., route, subarea, corridor, or system) are even harder to detect, and may not even occur or be perceived. For example, a 40-second time savings resulting from improvements to two adjacent intersections will be a major improvement at that scale and be appreciated by drivers using the intersections, but will not affect trip-making, route choices or even local air pollutant readings. At another location, however, similar improvements may divert drivers from other congested segments to the point where even local delay improvements are difficult to measure. In either case, some measures are not worth estimating, because they will not be observable after the proposed actions are implemented. Conversely, if these hard-to-detect changes are part of the problem statement and evaluation criteria, the scope of the action has to be extended or packaged with other actions until these impacts are detectable.

These considerations are shown graphically on Figure 5, which deals with bus lanes and similar actions that might be implemented to increase bus operating speeds and improve schedule adherence. Small savings in running times resulting from a limited action may be measured by the operator and even noted by riders, but not be sufficient to affect travel decisions and fleet requirements. A more extensive action may allow the operator to offer at least comparable service with fewer buses, producing savings in labor requirements and other operating costs; even further expansion may produce measurable ridership increases and mode shifts. However, if major savings in operating costs or energy use are desired, expensive actions normally beyond the scope of TSM (such as busways) may be required.

Preparing an Analysis Plan

A useful aid in determining the measures required for an analysis is to construct a flowchart of relevant evaluation factors and performance measures. Such a display can help an analyst decide if all evaluation factors are being addressed, if additional information is necessary to estimate evaluation measures, and if the proposed measures have compatible levels of detail. This mapping of measures is shown on Figure 6, which shows the analysis plan for a curb bus lane proposed for a major downtown street during peak commuting hours.

The action has been proposed to reduce transit operating costs by increasing operating speeds and reducing their variability. Reduced travel times on buses and improved access to employment sites (resulting from accompanying route modifications) may encourage more commuters to use transit. Improvements to traffic flow resulting from parking bans and turn prohibitions associated with the bus lane, however, will produce time savings for auto users and thus limit potential shifts in mode. Auto travel from corridors not affected by the bus lane will obscure the measurement of any changes in auto use. As a result, the primary evaluation of the lane can be limited to the measures shown in the left half of the flowchart.

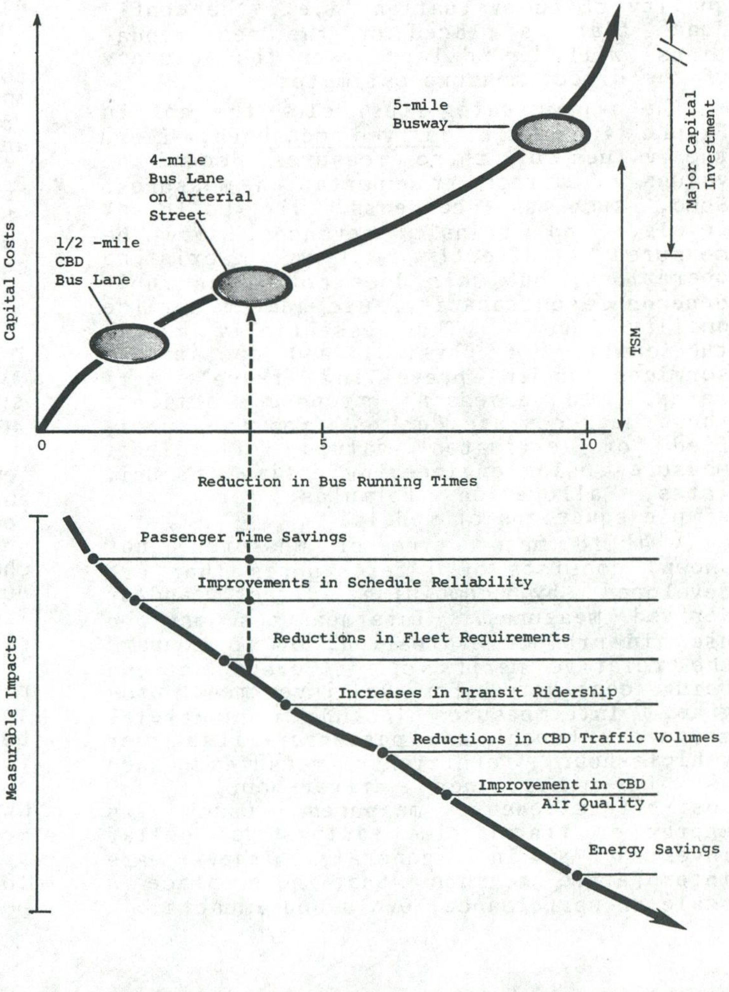

Figure 5. Typical effects of action scale on impact measurement.

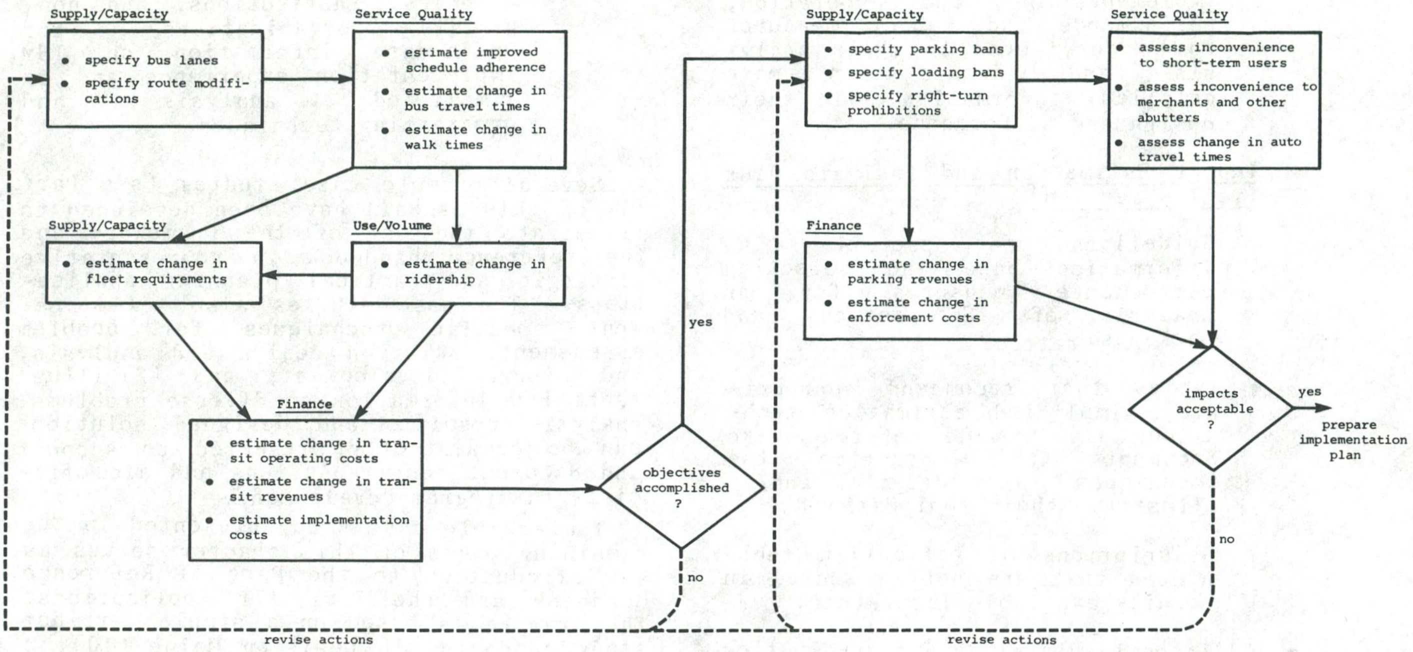

Figure 6. Sample analysis plan.

A ban on parking and loading is proposed to free lanes for buses, and right-turn restrictions are proposed at selected intersections to minimize conflicts between autos and buses. The right half of the flowchart shows that the potential impacts of these other package components also will be considered, and that the package may be modified if their impacts appear significantly negative. In most cases, a qualitative estimate of their magnitude is sufficient to assess the need to revise the package. Note that potential energy and air quality impacts are not estimated because they have no bearing on the design or implementation of a solution package in this particular study area, and they are not expected to be significant.

This is a simplified example. In a typical subarea, other problems probably would have been identified that would require analysis (such as auto circulation patterns or mode shares) in the primary evaluation step. Nonetheless, the example illustrates how a carefully structured analysis can limit the need for estimation, and focus efforts on the design of workable and acceptable solutions.

CHAPTER FOUR

APPLYING THE REFERENCE HANDBOOK IN PROJECT PLANNING

The Reference Handbook in Part II of this manual has been compiled to assist transportation agencies in applying the planning framework described in the preceding chapters. It provides practical guidance for transportation planners, traffic engineers, and transit operators in (1) identifying and screening potential solutions to their transportation problems, (2) determining information needed to make specific project decisions, and (3) selecting and applying techniques to produce this information. The major sections of the Reference Handbook, which are color-coded for easy reference, contain the following information:

- <u>Action Screening Aids (blue section)</u>
  - Tables that identify general approaches and types of TSM actions to consider in developing solutions to problems.
  - Profiles of TSM actions that present conditions where they are applicable, problems potentially encountered in their

implementation and operation, performance and impact measures to be considered in their analysis, and sources for more detailed information on their design and performance.

- Impact Estimation and Analysis Aids (yellow section)
  - Guidelines on preparing an information base and selecting performance measures for an analysis of TSM actions and packages.
  - Tables that recommend appropriate, simplified estimation techniques and provide references to documents that describe the techniques in detail and/or illustrate their application.
  - Descriptions of estimation techniques that are not presented in readily available literature.
- Additional Planning and Evaluation Aids (green section)
  - Notes on evaluation and packaging techniques.
  - A basic reference library for planners and engineers in small agencies and a list of the primary sources (i.e., federal agencies, institutions, and non-profit organizations) for up-to-date information on TSM implementation experience and on simplified analysis and programming techniques.

Several example case studies (see Part III of this manual) have been developed to illustrate the use of the framework and the reference handbook in representative strategic and tactical planning applications. The case studies also: (1) present specific techniques for problem assessment, solution design and analysis, and program development; and (2) illustrate how information on diverse problems, analysis results, and designed solutions can be consistently presented to support and document recommendations and aid officials in program development.

The example case study presented in the remaining pages of this chapter serves as an introduction to the Part II Reference Handbook and the Part III Applications. The example is based on a simple corridor study conducted in Lewiston Maine (10), a small, old industrial city with approximately 40,000 inhabitants. To emphasize the important aspects of each phase of the 4-phase project planning process, the presentation is more structured and formal than is necessary in an actual analyses. The case studies in Part III present more realistic applications of the process.

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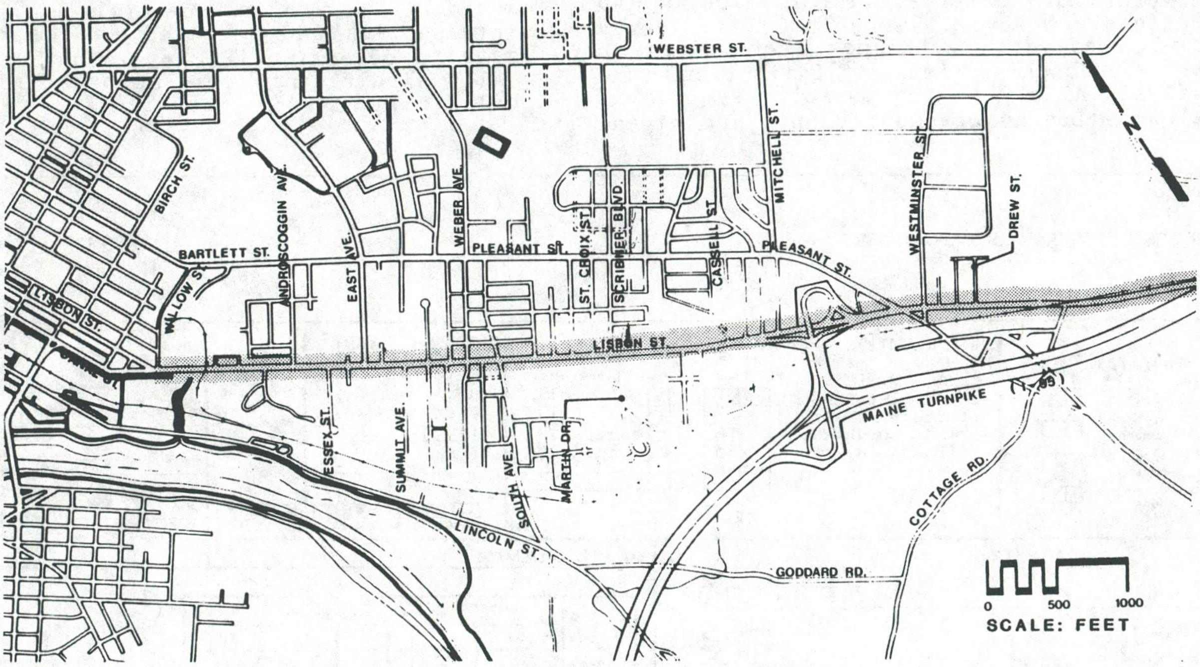
Case Study 1:
Lisbon Street Corridor

Purpose: This case illustrates (1) the 4-phase project planning process described in Chapter Three, (2) the use of the Reference Handbook in that process, and (3) the standard format of the case studies presented in Part III. It also shows the importance of careful problem assessment and of setting realistic design guidelines. The development of solutions in this small city setting was relatively straightforward once those tasks had been accomplished.

Site Description: The site, shown below, is a 2-mile corridor connecting the Lewiston (Maine's) CBD with residential districts and a turnpike interchange. Lisbon St., the major artery, is a two-lane street that carries between 5,000 and 8,000 vehicles per day. It is flanked by strip development, while the remainder of the corridor is mainly residential.

SITE MAP



PHASE 1: ANALYZE PROBLEMS AND THEIR SETTING

The study was prompted by accident and congestion-related problems noted in ongoing monitoring of the city's arterial street system, and by complaints from corridor residents and merchants concerning delays and unsafe driving conditions. City and state agencies flagged the corridor as probably needing improvement, and conducted field observations, counted turning and through movement at intersections (to supplement existing tube counts collected as part of on-going monitoring), made travel time runs, and compiled accident report data to provide information for a more rigorous assessment of existing conditions. The deficiency criteria shown below were used in that assessment, along with criteria on the physical condition of the road surface, curbs, signals, markings, and signs. These criteria are regularly used by the Maine DOT and city traffic departments to assess the operation and condition of urban arterial highways.

DEFICIENCY CRITERIA

- Supply/Capacity
  - lane width under 11' on a major artery
  - signs and pavement markings not in conformance with MUTCD
  - traffic control not in conformance with MUTCD standards
  - curb turning radii less than 20'
  - sight distance at intersections not in conformance with ITE/AASHTO standards

- Service Quality
  - intersection level-of-service lower than "C" (or critical lane volume in excess of 1200 cars per hour)
  - road segment level-of-service lower than "C" (or average lane volume in excess of 1200 cars per hour)
  - peak travel speed under 20 mph.

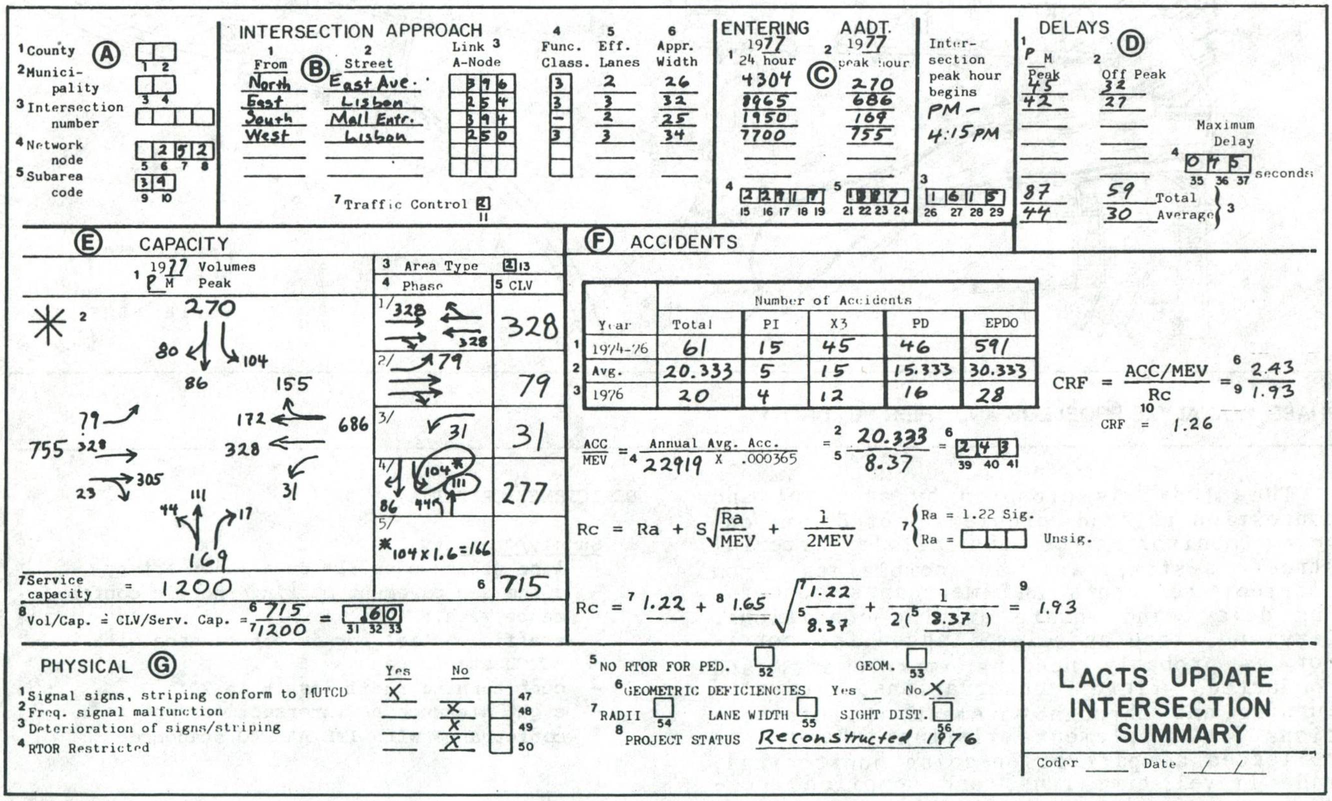
DEFICIENCY CRITERIA (continued)

- **Accidents**
  - 3-year average accident rate exceeds statewide average with 95% confidence; average rates;

signalized intersection:	1.22 per mill. entering vehicles
unsignalized intersection:	.39 per mill. entering vehicles
road segment:	3.74 per mill. vehicle-miles

Worksheets were prepared for use in the conditions analysis of intersections and road segments; a completed intersection worksheet is shown below. Much of the worksheet simply organized directly measured or observed information. Two sections, however, were used to apply simple analysis techniques recommended in the Handbook's Impact Estimation and Analysis Aids. In the capacity section (E below), turning movement counts and signal phase diagrams were used to identify critical lane volumes, with their sum used to calculate a service level ratio for the intersection (critical lane analysis). In the accident section (F below), a critical accident rate was determined for the intersection and compared to the observed rate to determine if there was a statistically significant accident problem (critical rate analysis).

INTERSECTION ANALYSIS WORKSHEET



Ⓐ
1 County ☐☐ (1 2)
2 Municipality ☐☐ (3 4)
3 Intersection number ☐☐☐☐
4 Network node ☐ 2 5 2 (5 6 7 8)
5 Subarea code 3 9 (9 10)

INTERSECTION APPROACH Ⓑ

1 From	2 Street	Link 3 A-Node	4 Func. Class.	5 Eff. Lanes	6 Appr. Width
North	East Ave.	396	3	2	26
East	Lisbon	254	3	3	32
South	Mall Entr.	394	–	2	25
West	Lisbon	250	3	3	34

7 Traffic Control 2 (11)

ENTERING AADT. Ⓒ

1 1977 24 hour	2 1977 peak hour
4304	270
8965	686
1950	169
7700	755
4 22919 (15 16 17 18 19)	5 1[illegible]7 (21 22 23 24)

Intersection peak hour begins PM – 4:15PM
3 1615 (26 27 28 29)

DELAYS Ⓓ

1 PM Peak	2 Off Peak	
45	32	
42	27	
87	59	Total
44	30	Average

3

Maximum Delay 4 045 (35 36 37) seconds

Ⓔ CAPACITY

1 1977 Volumes PM Peak

3 Area Type 2 (13)

4 Phase	5 CLV
1/ 328 328	328
2/ 79	79
3/ 31	31
4/ 86 104* 44 111	277
5/ *104 x 1.6 = 166	
6	715

7 Service capacity = 1200

8 Vol/Cap. ≐ CLV/Serv. Cap. = $\frac{^6 715}{^7 1200}$ = .60 (31 32 33)

Ⓕ ACCIDENTS

	Year	Number of Accidents Total	PI	X3	PD	EPDO
1	1974-76	61	15	45	46	591
2	Avg.	20.333	5	15	15.333	30.333
3	1976	20	4	12	16	28

$$\frac{ACC}{MEV} = \frac{\text{Annual Avg. Acc.}}{^4 22919 \times .000365} = \frac{^2 20.333}{^5 8.37} = ^6 \boxed{2.43}$$

(39 40 41)

$$Rc = Ra + S\sqrt{\frac{Ra}{MEV}} + \frac{1}{2MEV}$$

7 { Ra = 1.22 Sig.
Ra = ☐☐☐ Unsig.

$$Rc = ^7 1.22 + ^8 1.65 \sqrt{\frac{^7 1.22}{^5 8.37}} + \frac{1}{2(^5 8.37)} = ^9 1.93$$

$$CRF = \frac{ACC/MEV}{Rc} = \frac{^6 2.43}{^9 1.93}$$

10 CRF = 1.26

PHYSICAL Ⓖ

	Yes	No		
1 Signal signs, striping conform to MUTCD	X		☐	47
2 Freq. signal malfunction		X	☐	48
3 Deterioration of signs/striping		X	☐	49
4 RTOR Restricted		X	☐	50

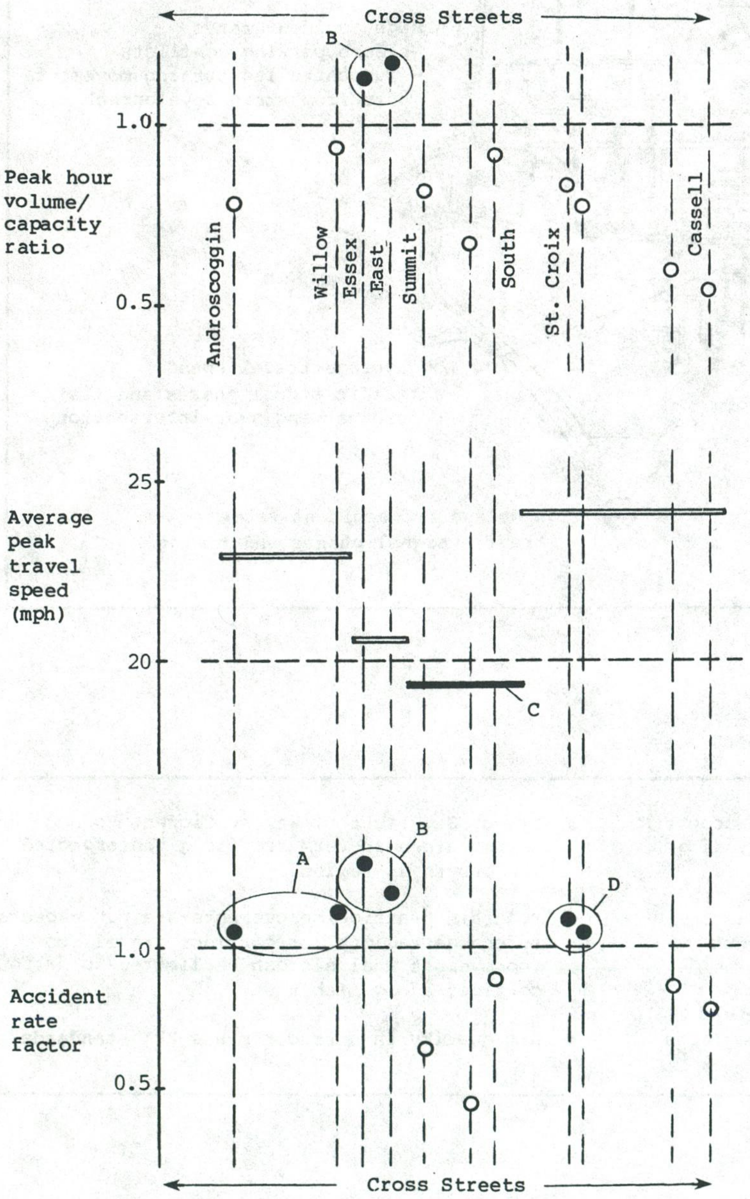
5 NO RTOR FOR PED. ☐ (52) GEOM. ☐ (53)
6 GEOMETRIC DEFICIENCIES Yes __ No X
7 RADII ☐ (54) LANE WIDTH ☐ (55) SIGHT DIST. ☐ (56)
8 PROJECT STATUS Reconstructed 1976

LACTS UPDATE INTERSECTION SUMMARY

Coder ____ Date __/__/__

The performance measures tabulated or calculated in the worksheets were plotted to provide profiles of conditions along the corridor artery; examples are shown below. These profiles showed which sections of the corridor had problems and where problems were likely to develop if traffic increased along or across the corridor. They also highlighted possible relationships among observed problems, for example, high congestion levels at the adjacent East and Essex St. intersections. The right-hand margin of the profiles notes problem causes determined through analysis and field observations.

PROFILES OF EXISTING CONDITIONS



Problem Causes (by location)

B. Essex/East:
- traffic signal operation

C. Summit to South:
- traffic signal operation
- curb parking near intersections

A. Willow to Androscoggin:
- awkward lane transition
- parked cars restrict sight distance at intersections
- conflicts between parking and moving cars

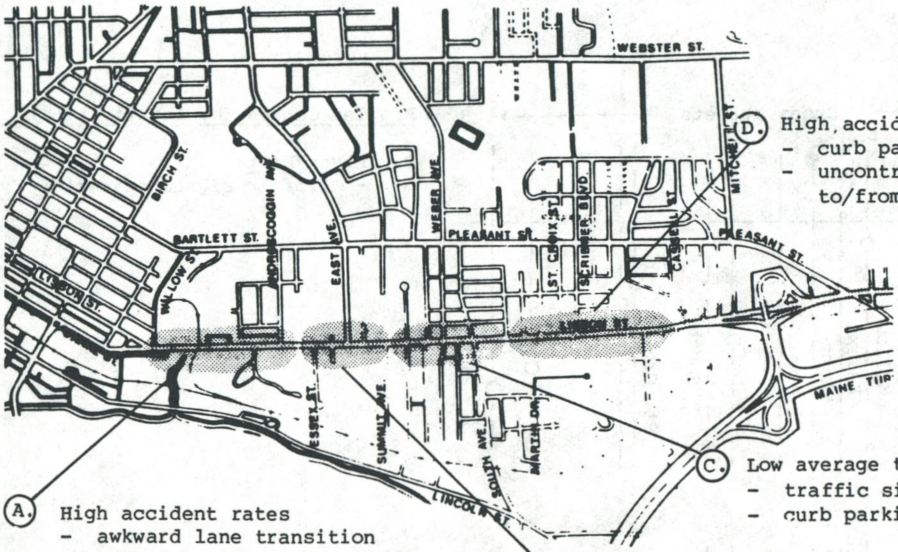
B. Essex/East:
- traffic signal operation

D. St. Croix to Cassell:
- curb parking conflicts
- uncontrolled turning movements to/from strip development

The problems identified in the assessment were summarized on a site map, as shown below. The problem map also shows the corridor segments, determined using problem similarities and interrelationships, that were used to simplify the analysis of solutions (in Phase 3).

Notes on existing and anticipated conditions in the corridor were made during the assessment to identify any constraints on and opportunities for improvement. These notes, also shown below, provided some of the feasibility conditions used to screen potential actions (during Phase 2).

PROBLEM SUMMARY



(D.) High accident rates
- curb parking conflicts
- uncontrolled turning movements to/from strip development

(C.) Low average travel speed
- traffic signal phases and timing
- curb parking near intersections

(A.) High accident rates
- awkward lane transition
- parked cars restrict sight distance at intersections
- conflicts between parking and moving cars

(B.) High delays and accident rates
- traffic signal phases and timing

NOTES ON PROBLEM SETTING

- Bartlett/Pleasant Sts. do not provide access to commercial establishments; any upgrading likely to be opposed by residents.
- No other feasible, parallel routes exist; Lincoln and Webster Sts. serve different corridors
- No land use changes expected in near-term that would change travel volumes or patterns in corridor.
- Lisbon St. right-of-way sufficient to accomodate near-term traffic given expected low growth in region.
- Moderate traffic improvements are not expected to change regional or corridor travel, so improvement analysis can be limited to narrow corridor along Lisbon St.
- Air quality in corridor meets EPA standards.

PHASE 2: IDENTIFY AND SCREEN CANDIDATE SOLUTIONS

Limited financial resources were available for solving the problems identified in Phase 1; accordingly, guidelines for screening potential solutions to reflect those limitations were developed by project engineers and the task force overseeing the project. The principal guidelines were as follows:

- Physical improvements were limited to those that required no new or minimal additional right-of-way.
- Management actions were limited to those with no institutional barriers that could prolong the implementation period.
- Operational actions were limited to those that could be accomplished with a minimum of new traffic control equipment.

The guidelines effectively limited consideration to traffic and parking operations and management improvements; ridesharing and transit actions were considered inappropriate or ineffective and discarded, and physical improvements were ruled out by cost limitations.

The Action Identification Tables in the Handbook would be applied at this point to identify candidate strategies and actions. A portion of the table for problems at isolated intersections is shown below; other strategies and actions would be obtained from the corridor problem table.

SAMPLE ACTION IDENTIFICATION TABLE (portion)

1 Action Identification Table 1:
Isolated Problems at Intersections or on Street Segments

Underlying Transportations Deficiencies	Corrective Strategies	Actions Applied at Intersections	Actions Applied on Street Segments
Problem 1: Vehicle Flow Conflicts and Accidents			
Turning and parking movements inhibit traffic flow	1A. Reduce delays and conflicts by separating flows	- New signals - Signal phasing and timimg changes - Turn lanes - Striping - Traffic police - Islands	- 2-way left turn lanes - Expanded off-street parking or loading areas - On-street parking restrictions or removal[1]
	1B. Reduce delays and conflicts by diverting movements	- Left turn prohibitions[1] - Jug-handles - On-street parking restrictions near intersections[1]	- Medians - Side street and curb cut closures - On-street parking restrictions or removal[1] - Expanded off-street parking or loading areas
Inadequate sight or stopping distances	1C. Increase time available for driver reaction	- New signals or stop signs - Signal phasing and timing changes[4] - Warning devices	- Speed restriction - On-street parking restrictions or removal[1] - Warning devices
Problem 2: Traffic Congestion			
Turning and parking movements inhibit traffic flow	2A&B. Same as strategies 1A&B listed for "Vehicle Flow Conflicts and Accidents"		
Inadequate capacity to handle peak traffic volumes	2C. Reduce delays by adding capacity	- New lanes[2] - Signal timing	

The screening guidelines established for the project, site conditions and professional judgment were used to screen the candidate strategies and actions for feasibility and effectiveness. The Action Profiles in the Handbook are designed to aid in the screening process; they describe conditions under which an action is likely to be applicable and effective, identify problems potentially encountered in implementing or operating the action, and cite reports that discuss the action's design and operation in detail. An example is shown below.

The worksheet on the following page illustrates the screening process. The "candidate strategies/actions" column lists appropriate strategies and actions cited in the Action Identification Tables; the "notes and comments" column lists feasibility, effectiveness, and other assessments made by the project engineer and his staff; and the "Pursue?" column presents the judgments of the engineer.

SAMPLE ACTION PROFILE (portion)

8

Profile 8: On-Street Parking Bans During Peak Periods

Curb lanes designated for parking can provide an inexpensive resource for increasing a street's traffic carrying capacity, particularly if periods of heavy traffic flow do not overlap with periods of high parking use. Parking bans near intersections also can provide space for turning lanes or additional through lanes, increasing an intersection's capacity.

Problems Addressed:

- Traffic congestion consistently develops in an employment center or along an arterial street during peak travel periods.
- Delays at intersections contribute to air pollutant concentrations in excess of standards.

Conditions for Application:

- Absence of high-turnover, high-occupancy parking - Commercial establishments such as newsstands, dry cleaners, drug stores, and convenience stores are patronized by people making quick stops on their way to or from work. Unless very convenient parking is available to patrons of these stores, either off-street or along side streets, a curb parking ban will be difficult to enforce and will be strongly opposed by store owners.
- Absence of other curb uses - The use of the curb lane by buses, taxis or autos stopped to pick up or discharge passengers, or by truck loading or unloading goods will lower its capacity for moving vehicles. If the curb lane currently is heavily used for these purposes, a parking ban will likely be ineffective unless other controls are established, such as a loading ban or a bus-only operation.
- Space for turning movements - The curb lane is part of the turning radius normally available to cars turning into or out of the right-hand travel lane. If turning volumes are high and turning movements are hampered by reduced radii, the capacity added by the new lane may be minimal, and accidents may increase.
- Pedestrian buffer - Cars parked in the curb lane provide a buffer between pedestrians and vehicular traffic. If the curb directly abuts a narrow or heavily-used sidewalk, the use of the curb lane by moving vehicles may present a hazard to pedestrians.

Potential Evaluation Factors:

- Congestion reduction:
  - change in average travel speed or level-of-service along streets affected by the action, including parallel arteries on which parking is not restricted (5% to 20% improvement possible depending on existing congestion and midblock interference levels)
- Street operations:
  - signing and other implementation costs
  - change in parking enforcement costs
  - change in parking revenues, including fines
- Commercial activity:
  - change in sales of commercial establishments along street
  - change in number of patrons entering stores during hours of parking ban
- Transit operations:
  - change in operating costs of transit routes serving the corridor or center

References:

(1) D.C. Department of Transportation, Metropolitan Police Department, Office of the Corporation Counsel, "Improved Parking and Traffic Enforcement in the District of Columbia" (April 1977) 45 pp.

(2) Peat, Marwick, Mitchell and Company, "Study of Parking Management Tactics, Volume 2: Overview and Case Studies," Report No. FHWA-PL-79- 021 (December 1979) 237 pp.

Boston MA case study discusses a peak period ban in the downtown.

(3) Pontier, W.E., P.W. Miller and W.H. Kraft, Edwards and Kelcey, Inc., "Optimizing Flow or Existing Street Networks", NCHRP Report 113, Washington DC (1971) 414 pp.

Presents a "before-after" analysis of parking restrictions near intersections in Louisville (KY) and Newark (NJ).

ACTION SCREENING WORKSHEET

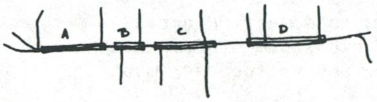
CANDIDATE STRATEGIES/ACTIONS	NOTES/COMMENTS	PURSUE?
● Separate traffic flows at intersections to reduce accidents and delays		
- new traffic signals	- major intersections already signalized	No
- separate turn phases	- significant turning movements at 5 intersections	Yes
- left-turn lanes	- ditto; adequate right-of-way, but need to remove parking	Yes
- striping/islands	- probably useful at some locations	Yes
● Separate traffic flows on street segments to reduce delays		
- two-way left turn lanes	- inadequate right-of-way	No
● Divert turning movements to reduce accidents and delays		
- left-turn prohibitions	- added traffic on side streets and driver confusion rule this out	No
- street and curb-cut closures	- no alternative entrances to many abutting properties; entrances to some side streets could be closed but this would hinder access to off-street parking and residences; must be done selectively	Maybe
- medians	- added travel distances and increased turns at intersections (including illegal U-turns) would disrupt traffic more than existing midblock turns	No
● Move parking from street to reduce accidents and delays		
- remove parking near intersections	- adequate vacancy rate in nearby spaces along most of corridor, so little opposition expected from merchants	Yes
- remove parking in midblock	- in most locations, adequate off-street or side street parking exists near stores; may need to retain parking in some blocks of Libson St.	Yes
- add off-street parking	- not needed, vacant spaces can absorb cars currently parking on Lisbon St.	No
● Increase time for driver reaction to avoid accidents		
- new signals, signs or warning devices	- most intersections meet signal and signing standards, but some signing could be improved	Yes
- parking removal near intersections	- should be effective in improving sight distance at problem	Yes
● Add capacity at intersections to reduce delays		
- new lanes	- can use width of parking lanes to add turning or through lanes if curb radii are increased	Yes
- signal timing	- retiming signals will add effective capacity to at least two intersections	Yes
● Add capacity on street segments to reduce delays		
- new lane	- existing parking lanes can be safely used as travel lanes if curb radii are increased	Yes
● Add street capacity to corridor to reduce delays		
- new segments or lanes on parallel streets	- not feasibile in residential neighborhoods	No
● Improve use of existing corridor capacity to reduce delays		
- signal coordination	- physically interconnecting Essex/East St. signals should be considered; manual coordination probably adequate elsewhere	Yes
- reversible lanes	- inadequate right-of-way; balanced traffic	No
- one-way pairs	- too much local traffic; no good route for other half of pair	No

Actions surviving the screening were combined into two initial packages for analysis, as shown below. The first contained the minimum improvements needed to solve the problems identified along the corridor. It would improve traffic flow and reduce conflicts among flows by: (1) removing parking, (2) using the freed lanes for travel or turning movements, and (3) modifying signal operations. Curb radii increases would be required at most intersections to allow right turns to be made to and from the curb lane, and traffic signals would have to be relocated or replaced at several locations to be visible from all approach lanes; therefore, these changes were noted so that they would be included in project specifications and cost estimates.

A minor widening of the right-of-way along one section of the corridor artery was identified during field inspections as good opportunity to further reduce delays and improve traffic flow. Consequently, a second package was defined that included this action, even though its implementation probably would be deferred by limited funds.

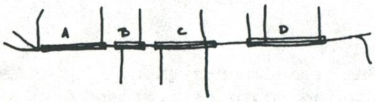
INITIAL ACTION PACKAGES

Package #1: improvements requiring only a small amount of new traffic control equipment and no new right-of-way



- All sections:
  - increase curb radii
  - remove parking near major intersections
- Section A (Willow to Androscoggin):
  - add turn and travel lanes through restriping
- Section B (Essex to East):
  - connect traffic signals
  - add turn lanes and phases
- Section C (Summit to South):
  - restripe for 2 approach lanes at intersections
- Section D (St. Croix to Cassell):
  - remove parking
  - restripe for 2 lanes in each direction

Package #2: improvements requiring only a small amount of new traffic control equipment and/or right-of-way



- All actions included in Package #1
- Section A:
  - widen to add travel lanes

PHASE 3: DESIGN, ANALYZE, AND EVALUATE SOLUTIONS

A simple evaluation approach could be developed in this case based on the guidelines presented in the Impact Estimation and Analysis Aids in the Reference Handbook. The factors and criteria selected for assessing proposed solutions follow. Many are identical to the deficiency criteria used in Phase 1, and only a few required the estimation of performance measures. Safety and pedestrian circulation factors, for example, were treated as design criteria.

The Action Profiles in the Reference Handbook list potential evaluation factors and corresponding performance and impact measures that might be applied in the analysis of specific types of TSM actions.

DESIGN AND EVALUATION CRITERIA

- Supply/Capacity
  - travel lanes at least 11' wide; left-turn lanes at least 10' wide
  - signs, signals and pavement markings in conformance with MUTCD standards
  - turning radii at least 20'
- Safety

a) vehicles
- provide adequate separation between turning and through traffic

b) pedestrian
- provide adequate buffer between curb travel lanes and sidewalk flows
- provide safe crossing time during each signal cycle

DESIGN AND EVALUATION CRITERIA (continued)

- Service Quality

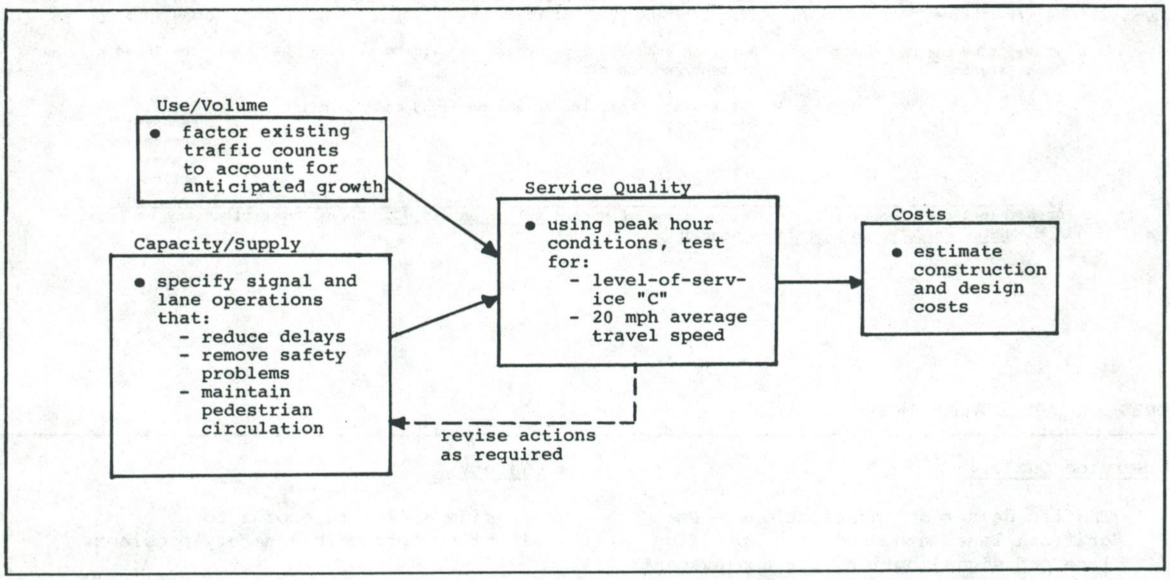
  a) moving vehicles
    - LOS C or higher at intersections and along street segments
    - peak travel speed at least 20 mph.

  b) parking
    - provide spaces within 300' of all stores

- Financial
    - implementation budget limited to $200,000

The analysis plan developed for the case study is diagrammed below. The plan addresses all the evaluation factors and criteria, and problem setting and screening information were used to simplify the analysis where possible. The major simplifying factor was the absence of (1) significant growth in the corridor, and (2) actions that might change travel patterns.

ANALYSIS PLAN



The Impact Estimation Aids section of the Reference Handbook contains (1) guidelines on selecting and applying estimation techniques, and (2) tables that recommend specific techniques for common analysis situations. A portion of the Method Selection Table for service quality is shown on the following page.

The techniques selected for carrying out the analysis plan also are presented on the following page, along with notes on their application.

SAMPLE METHODS SELECTION TABLE (portion)

Methods Selection Table 2:
Travel Time Estimation

2

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
<u>Spot or Segment Analysis</u>		
• Vehicular delays at intersections		
– check for acceptable level-of-service	– use capacity adequacy techniques cited in the Methods Selection Table for Supply/Capacity estimation	
– estimate average travel time, delay or queue duration	– apply analytical techniques and worksheets	1-5
	– apply simulation models of signalized intersection operations (mainly applicable to complex, high-volume intersections)	8,9
– set signal timing to minimize delays	– apply Webster's equation or similar procedure	7
• Vehicular travel time along roadway segment		
– check for acceptable level-of-service	– use capacity adequacy techniques cited in the Methods Selection Table for Supply/Capacity estimation	
– estimate average travel time	– use curves relating speed to volume/capacity ratio for different types of roadways	1,6 see TN #3
• Travel time along transit route segment	– apply an analytical procedure to calculate route segment running times	see TN #4
	– use average operating speeds observed under similar conditions	21,22, see Profile Sheets for transit actions

* For numbered references, refer to text section of <u>Method Selection Aid #2</u>. Tech. Notes cited may be found in the <u>Notes on Selected Techniques</u> Section.

TECHNIQUES AND APPLICATION NOTES

- <u>Service Quality</u>
  - Traffic delays at intersections – Use critical lane method to test specific lane and signal options for achievement of level-of-service C during peak hour.
  - Average travel speed – Intersection improvements and parking restrictions should be sufficient to meet 20 mph standard. Proposed phasing sequences should be checked for interference.
  - Parking availability – Field survey showed vacancy rates along side streets and in adjacents lots are adequate to accomodate any reductions in on-street spaces.
  - Pedestrian access and circulation – Existing sidewalks and crosswalks are sufficient to accommodate increased flows. Anticipated pedistrian and turning traffic volumes do not warrant phase separations. Signal timing must continue to allow adequate crossing time for pedestrians.

- <u>Safety</u>

  Examine accident records to identify correctible safety problems.

- <u>Supply/Capacity</u>

  Specify different signal phasings and lane configurations and operations for analysis.

- <u>Financial</u>

  Prepare cost estimates for engineering and construction/implementation of recommended actions. Changes in on-going street maintenance costs are expected to be minimal.

- <u>Public Costs</u>
  - Accidents – Intersection safety improvements identified in safety analysis should sufficiently reduce accident rates.
  - Air quality – No problems exist or are anticipated in the corridor.

The design and operation of seven intersections, and of short segments between three pairs of these intersections, were key in solving the safety and delay problems, so these locations were examined first. The principal "techniques" selected for design and analysis at these locations were:

- A detailed examination of accident records and safety conditions.
- The application of "good traffic engineering practice" to specify operational plans.
- The use of critical lane analysis and Webster's signal timing equation to test for operation at level-of-service C or higher.

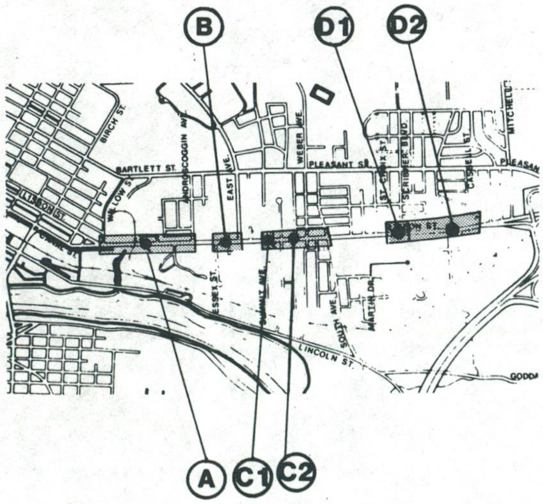
The worksheets developed for Phase 1 were used in the critical lane analysis.

Once functional designs had been developed for the key intersections and segments, the same techniques were applied to the remainder of the corridor as necessary to address remaining safety, delay, and speed problems and to provide lane continuity and transitions along the corridor artery. A final check of signal phasing and timing was made to ensure no conflicts were introduced between intersections that could lead to delays and queues. Finally, state summaries of bid data were used to estimate final engineering and implementation costs.

PHASE 4: RECOMMEND AN ACTION PLAN

The cost of implementing the designed solution was approximately $200,000, which was expected to require a phased implementation over a 3- to 5-year period because of funding limitations. As a result, the corridor planning team grouped the recommended improvements into three logical stages for final engineering and construction, as shown below. The first two stages covered improvements that (1) addressed the most significant problems and (2) were feasible for implementation in the first 2 or 3 years. The "potentially deferred" improvements were to be designed along with stage 2; they might be implemented in that stage if additional funds became available, but most likely would be implemented in the fourth or fifth year.

RECOMMENDED ACTION PLAN



<u>Stage 1</u> ($55,000):

- Section A (Willow to Androscoggin)
  - restripe for 1 eastbound and 2 westbound lanes
  - paint transition zone to start of curb parking
  - increase curb radii
- Section B (Essex to East)
  - change lane use designations
  - change traffice signal phases and timing
  - increase curb radii

<u>Stage 2</u> ($60,000):

- Section C1 (South St.)
  - relocate traffic signal heads
  - prohibit parking near intersections
  - restripe for 2 approach lanes
  - increase curb radii
- Section D1 (St. Croix to Scribner)
  - remove parking and restrip for 2 lanes in each direction
  - upgrade traffic signal hardware
  - increase curb radii

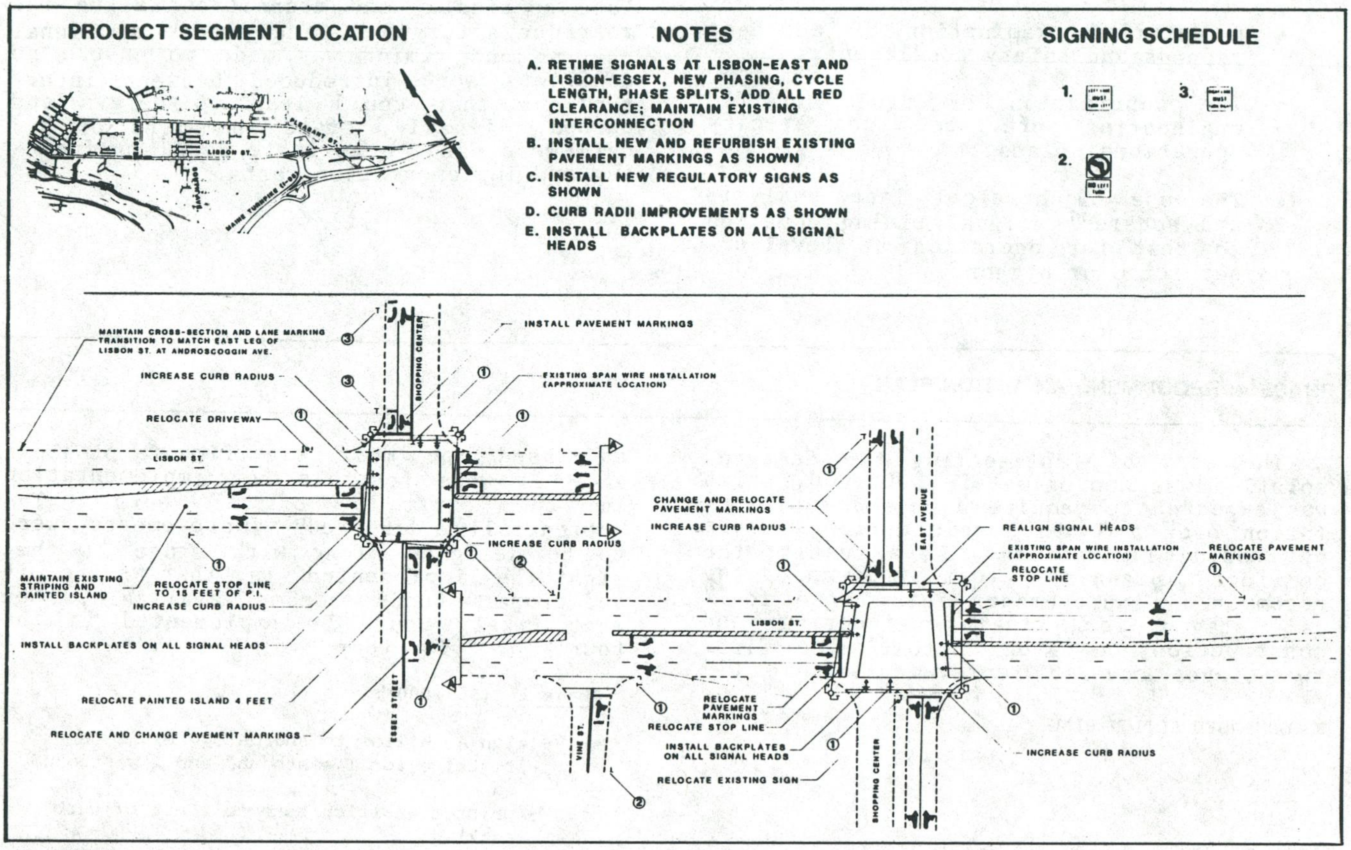
<u>Potentially Deferred</u> ($75,000):

- Section C2 (Summit to Dumont)
  - prohibit parking near intersections
  - restripe for 2 approach lanes
  - increase curb radii
- Section D2 (Apple to Cassell)
  - remove parking and restripe for 2 lanes in each direction
  - increase curb radii

Detailed diagrams of the recommended improvements were prepared to carefully document the action plan for engineers and implementing agencies; an example is shown below.

Portions of the plan have been implemented, and the remainder will be scheduled as funds become available.

SEGMENT IMPROVEMENT DIAGRAM



NOTES

A. RETIME SIGNALS AT LISBON-EAST AND LISBON-ESSEX, NEW PHASING, CYCLE LENGTH, PHASE SPLITS, ADD ALL RED CLEARANCE; MAINTAIN EXISTING INTERCONNECTION
B. INSTALL NEW AND REFURBISH EXISTING PAVEMENT MARKINGS AS SHOWN
C. INSTALL NEW REGULATORY SIGNS AS SHOWN
D. CURB RADII IMPROVEMENTS AS SHOWN
E. INSTALL BACKPLATES ON ALL SIGNAL HEADS

PART II
REFERENCE HANDBOOK

TSM Screening Aids

Transportation Systems Management (TSM) is a broad concept covering a variety of physical, operational, regulatory, and managerial actions that can be quickly and cheaply designed and implemented to affect the use and performance of transportation facilities. Only a few of these actions, however, are likely to be feasible and effective means of solving any specific problem. Planners, engineers, and other problem-solvers need to quickly focus their analysis and design efforts on the few appropriate actions if a solution is to be implemented in the near-term.

Two screening aids are presented to assist transportation agencies in selecting candidate TSM actions that are likely to be feasible and effective in solving their particular problems. The first, a set of Action Identification Tables, identifies approaches to solving general problems in which transportation agencies are commonly involved, and lists TSM actions that could be implemented separately or in combination as part of each approach. The second, a set of Action Profiles, provides guidelines on the applicability of several of the actions identified in the tables, along with design and operational considerations and other information.

TSM Action Identification Tables

The Action Identification Tables that follow are designed to assist agencies in identifying general approaches and specific types of TSM actions that are potentially applicable in solving short-term transportation problems. The tables are organized around five factors or parameters that are helpful in identifying potential solutions; these are:

- Location or scale of problem.
- Nature of (perceived) problem.
- Underlying deficiency in transportation system.
- Strategy or approach to solution.
- Location or scale of action implementation.

An engineer or planner should use these parameters in sequence to identify appropriate TSM actions for further analysis and eventual implementation, as discussed in the following.

The <u>location or scale of a problem</u> is a major determinant of the types of actions that may be required for its solution or mitigation. Six basic problem locations are covered by the tables:

1. Spot locations (intersections) and segments (streets)
2. Corridors
3. Residential communities
4. Employment centers
5. Commercial centers
6. Regional

While this is not an exhaustive list, most other problem locations will resemble one or more of the types on this list. Some may be composites that require the user to examine more than one table; the most obvious example is a central business district that functions both as an employment center (covered in Table 4) and a commercial center (covered in Table 5).

Each problem location table covers three to six types of <u>problems</u> commonly addressed at least in part, by urban transportation agencies. These problems are listed in the following table.

PROBLEMS COVERED IN ACTION IDENTIFICATION TABLES

---

1. Isolated Intersections or Street Segments
    - Vehicle Flow Conflicts and Accidents
    - Traffic Congestion
    - Pedestrian Safety
2. Corridors
    - Traffic Congestion on Freeways
    - Traffic Congestion on Arterial Streets
    - Crowded Transit Vehicles
    - Traffic Congestion on Cross-Corridor Roads
3. Residential Communities
    - Through Traffic on Residential Streets
    - Declining Sales in Town Centers
    - Inadequate Transit Service
    - Traffic Congestion in Town Centers
    - Unsafe or Inadequate Routes for Pedestrians and Cyclists
4. Employment Centers
    - Traffic Congestion in or near Center
    - High Commuting Cost or Inadequate Access to Workforce
    - Substandard Air Quality
    - Lack of Business Expansion Space
    - Unsafe Pedestrian Circulation
    - Commuter Parking on Residential Streets near Center
5. Commercial Centers
    - Traffic Congestion in or near Center
    - Community Resistance to Commercial Expansion Plans
    - Crowded or Unsafe Pedestrian Circulation
6. Regional (including State and National)
    - High Transit Operating Cost and Deficits
    - High Energy Consumption
    - Vulnerability to Energy Supply Disruption
    - Unacceptable Air Quality
    - High Accident or Insurance Rates
    - Constrained Mobility of Non-Drivers

Again, the problem names and table organization should not be rigidly applied. For example, in dealing with a traffic congestion problem at three or four intersections along an arterial street, a planner should look at both the isolated intersection (Table 1, Problem 2) and the corridor (Table 2, Problem 2) tables to identify potential solutions.

Problems perceived by transportation officials and others often arise from different types of underlying deficiencies (e.g., conflicts between pedestrians and turning vehicles). Some common deficiencies are listed for each problem (in the first column of the tables) to help planners address problem causes and not secondary symptoms. Note that the tables identify only those deficiencies associated with the transportation system. For example, although declining sales in town center (Table 3, Problem 2) might be exacerbated by the listed transportation deficiencies (e.g., heavy use of center streets by through traffic), changes in the socioeconomic characteristics of residents and increased competition from shopping centers are likely to be more significant causes of the problem.

Different approaches or strategies (e.g., add capacity or reroute through-traffic) can be pursued in solving many problems, and appropriate strategies for each deficiency are indicated in the second column of the tables. In practice, a planner often would use a combination of strategies to address a problem, because a combination of deficiencies is present in most cases. For example, to deal with a problem of through-traffic on residential streets (Table 3, Problem 1), a combination of reducing travel times on adjacent arterial streets and blocking through-routes over residential streets might be examined, with the strategy mix depending on local conditions. The identification of distinct strategies in the tables, however, helps set specific objectives to guide the design, evaluation, and packaging of TSM actions.

The actions listed for each strategy are grouped by scale or location of implementation to help combine problems for analysis and solution, establish appropriate study area boundaries, and identify agencies and groups that should be involved in planning and implementing a solution package. For example, many of the problems associated with an employment center will require actions both within the center and along major approach corridors, so limiting the study area to the center will produce only partial solutions to those problems.

The actions listed for each scale or location category are in no particular order, i.e., the last listed is not necessarily less effective than the first. Most actions listed under "throughout urban area," however, should be viewed as supportive or supplemental to other, more focused actions, and would typically be a part of a solution package addressing a problem that is widespread.

Many of the actions listed may be familiar to an agency and simple to plan and implement, while others will require careful planning or the involvement of other agencies. Profiles on several actions outside the experience of many communities are provided in the next section of the Handbook to assist agencies in planning and designing these actions.

1

Action Identification Table 1: Isolated Problems at Intersections or on Street Segments

Underlying Transportations Deficiencies	Corrective Strategies	Actions Applied at Intersections	Actions Applied on Street Segments
Problem 1: Vehicle Flow Conflicts and Accidents			
Turning and parking movements inhibit traffic flow	→ 1A. Reduce delays and conflicts by separating flows	- New signals - Signal phasing and timimg changes - Turn lanes - Striping - Traffic police - Islands	- 2-way left turn lanes - Expanded off-street parking or loading areas - On-street parking restrictions or removal[1]
	1B. Reduce delays and conflicts by diverting movements	- Left turn prohibitions[1] - Jug-handles - On-street parking restrictions near intersections[1]	- Medians - Side street and curb cut closures - On-street parking restrictions or removal[1] - Expanded off-street parking or loading areas
Inadequate sight or stopping distances	→ 1C. Increase time available for driver reaction	- New signals or stop signs - Signal phasing and timing changes[4] - Warning devices	- Speed restriction - On-street parking restrictions or removal[1] - Warning devices
Problem 2: Traffic Congestion			
Turning and parking movements inhibit traffic flow	→ 2A&B. Same as strategies 1A&B listed for "Vehicle Flow Conflicts and Accidents"		
Inadequate capacity to handle peak traffic volumes	→ 2C. Reduce delays by adding capacity	- New lanes[2] - Signal timing	
Problem 3: Pedestrian Safety			
Conflicts between pedestrian and vehicular traffic	→ 3A. Reduce conflict by separating flows	- Islands - New signals[3] - Signal phases - Crosswalk striping - Traffic police	

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[1] Restrictions may be limited to hours of peak traffic flow.

[2] Lanes may be added through parking removal, re-striping and/or widening.

[3] New pedestrian signals may be demand-actuated or tied to existing (or modified) progression.

[4] Changes could include an all-red phase or extended amber.

Action Identification Table 2: Problems in Corridors

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied Along Corridor	Actions Applied in Subareas in or near Corridor	Actions Applied throughout Urban Area
Problem 1: Traffic Congestion on Freeways or other Major Facilities (such as Bridges or Tunnels)				
Insufficient capacity to handle peak traffic volumes at acceptable service level	1A. Reduce travel delays by adding capacity to facility	- New lanes reserved for buses and carpools - New reversible lanes - Extended ramps and merge zones		
	1B. Reduce travel delays through more effective use of existing capacity	- Ramp metering - Contra-flow or reversible lanes - Ramp closures - Travel in breakdown lane during peak		
	1C. Reduce travel delays by encouraging travelers to use transit and carpools	- Bus and carpool lanes - Ramp meter bypasses - Park/ride lots - Park/pool lots - Added express buses - Extended feeder bus routes	- Bus and carpool ramps and lanes - Modified transit distribution routes - Increased parking fees - Carpool priority in parking lots - Employer pooling programs - Employer subsidy of transit passes	- Transit passes - Bus and carpool information and marketing
	1D. Reduce travel delays by encouraging trips to be made at less-congested times	- Reduced off-peak or increased peak tolls	- Flexible working hours - Reduced off peak or increased peak parking rates	
	1E. Reduce travel delays by encouraging short trips to use arterial streets	- Ramp metering - Ramp closures	- New lanes and segments - Signal coordination - Street and intersection geometry improvements	

2 Action Identification Table 2: Problems in Corridors

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied Along Corridor	Actions Applied in Subareas in or near Corridor	Actions Applied throughout Urban Area
Problem 2: Traffic Congestion on Arterial Streets and Highways				
Insufficient capacity to handle peak traffic volumes at acceptable service level	2A. Reduce travel delays by adding capacity in corridor	- New lanes - New segments paralleling or bypassing congested segments - Under/overpasses		
	2B. Reduce travel delays through more effective use of existing capacity[1]	- Peak period on-street parking and loading bans - Signal timing and phases - Signal coordination - Modified intersection geometry - Reversible lanes - 2-way left-turn lanes - Medians - Turn prohibitions or rerouting - Access control - One-way pairs		
	2C. Reduce travel delays by encouraging travellers to use transit and carpools	- Bus and carpool lanes or bypasses - Signal preemption - Limited-stop or express buses - Expanded bus routes - Increased bus frequency - Park/ride lots	- Modified transit routes - Employer pooling programs - Employer subsidy of transit passes	- Transit passes - Bus and carpool information and marketing
	2D. Reduce travel delays by encouraging trips to be made at less-congested times		- Flexible working hours - Reduced off-peak or increased peak parking rates	
	2E. Reduce travel delays by encouraging trips to use parallel freeways	- Actions listed under strategies 1A and 1B: Reduce travel delays by adding capacity to freeways or through making more effective use of their existing capacity	- Geometric and signalization improvements on access roads	

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[1] Many of the actions listed may be applied on cross streets to allow more green time on the corridor artery (while maintaining level of service on the cross streets).

Action Identification Table 2: Problems in Corridors

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied Along Corridors	Actions Applied in Subareas in or near Corridor	Actions Applied throughout Urban Area
Problem 3: Crowded Transit Vehicles				
Crowded buses slow running times and inconvenience passengers	3A. Reduce peak load factors by adding capacity to corridor	- Increased frequency on existing routes - New express or limited-stop service - New local bus routes		- Articulated buses - Expanded transit fleet
	3B. Reduce peak load factors by diverting trips to off peak times	- Increased frequency in shoulder periods	- Flexible working hours	- Reduced off-peak fares - Increased peak fares
Problem 4: Traffic Congestion on Cross-Corridor or Access Roads				
Insufficient capacity to handle peak traffic volumes at acceptable service level	4A. Reduce travel delays by creating new access paths		- New segments - Intersection realignment - Signals and phases - Signal coordination	
	4B. Reduce travel delays by increasing the effective capacity of existing roads		- New segments - New lanes - Street and intersection geometry improvements - Access control - Signal coordination	

3 Action Identification Table 3: Problems in Residential Communities

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied in or near Town Center	Actions Applied in or near Neighborhoods	Actions Applied throughout Urban Area
Problem 1: Through Traffic on Residential Streets				
Delays on main streets providing alternative routes	1A. Reduce travel times on existing arterial routes		- New lanes - Street and intersection geometry - Signal coordination - Parking removal or restrictions	
	1B. Create new & faster route(s)		- New segments - Street and intersection geometry - Signal coordination	
Main streets provide less direct routes	1C. Increase travel time and reduce directness on routes using residential streets		- Speed control devices - One-way streets with offsets - Barriers across segments and intersections	
Problem 2: Declining Sales in Town Centers				
Inadequate access from neighborhoods	2A. Reduce auto travel time from neighborhoods to center	- New segments - Street geometry - Added parking		
	2B. Improve service quality of non-auto access from neighborhoods to center	- Merchant delivery or shopper vans - Merchant transit rebates - Bicycle/moped storage - Waiting shelters	- Modified bus routes - Community transit - Shared-ride taxi - New walkways and and crossings - Bikeways	- Reduced transit fares for short, off-peak trips - Bus specifications that aid passengers with packages
Inadequate or unsafe pedestrian circulation within center	2C. Reduce pedestrian travel time within center	- Street closures - Wide sidewalks - New crossings		
	2D. Reduce conflicts between vehicles and pedestrian traffic	- Street and intersection geometry - Signals and phases - Traffic flow management - Street closures		
Heavy use of center streets by through traffic	2E. Divert through traffic to new or improved alternative routes	- New segments and lanes - Signal coordination - Speed control devices - Street closures - Traffic flow management		

Action Identification Table 3: Problems in Residential Communities

3

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied in or near Town Center	Actions Applied in or near Neighborhoods	Actions Applied throughout Urban Area
Problem 3: Inadequate Transit Service				
Inadaquate alternatives to auto travel for intra-town trips	3A. Improve coverage and convenience by modifying existing routes and schedules	- Coordinated schedules - Waiting shelters - Transfer center	- Modified bus routes	- Reduced fares for short, off-peak trips - Extended service hours
	3B. Improve coverage and convenience by developing new service		- Community transit - Shared-ride taxi - Family passes	
Inadequate access to major centers outside town	3C. Improve convenience of access to regional transit routes		- Extended or modified routes - Community feeder transit - Park/ride lots - Timed transfers	
	3D. Improve service quality on regional transit routes			- Reduced policy headways - New circumferential routes - Added express or limited-stop service - Extended service hours
Problem 4: Traffic Congestion in Town Centers				
Inadequate street capacity	4A. Reduce travel delays through more effective use of existing capacity	- Street and intersection geometry - Signals and phases - Traffic flow management - Access control - Reduced on-street parking - Parking enforcement		
Inadequate parking capacity	4B. Increase utilization of existing spaces	- Time limits and increased rates for convenient spaces - Traffic flow controls to encourage use of remote lots		
	4C. Increase parking capacity	- New or expanded off-street lots or garages - Side street conversion to parking		
	4D. Improve service quality on other modes to encourage their use	- Actions listed under strategy 2B: Improve non-auto service quality from neighborhoods to town center	- Actions listed under strategy 2B: Improve non-auto service quality from neighborhoods to town center	- Actions listed under strategy 2B: Improve non-auto service quality from neighborhood to town center

3 Action Identification Table 3: Problems in Residential Communities

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied in or near Town Center	Actions Applied in or near Neighborhoods	Actions Applied throughout Urban Area
Problem 5: Unsafe or Inadequate Routes for Pedestrians and Cyclists				
Unsafe routes →	Improve safety of existing routes	- New sidewalks and crosswalks - New signs and signals - Signal phase changes - Wider sidewalks - Curb parking restrictions	- New sidewalks and crosswalks - New signs and signals - Signal phase changes	
Inadequate routes →	Add new routes and conveniences	- New sidewalks and crosswalks - New signs and signals - Signal phase changes - Bideways - Bicycle racks or lockers - Pedestrian/ bicycle bridges	- New sidewalks and crosswalks - New signs and signals - Signal phase changes - Bikeways - Pedestrian/ bicycle bridges	

Action Identification Table 4: Problems at Employment Centers

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied in or near Center	Actions Applied along Approach Corridors	Actions Applied throughout Urban Area
Problem 1: Traffic Congestion In or Near Center				
Insufficent street capacity to handle peak traffic volumes at acceptable service levels	1A. Reduce travel delays through more effective use of existing capacity	- New signals and phases - Signal coordination - Reversible lanes - On-street parking and loading bans - Turn restrictions - One-way street system		
	1B. Reduce travel delays by adding capacity	- New lanes and segments		
	1C. Reduce travel delays by encouraging commuters to use transit and carpools	- Bus/carpool priority measures - Parking fees and space assignment - Bus pass subsidy - Employer pooling programs - Modified transit distribution routes	- Expanded bus service - Express bus - Bus schedule coordination - Park/ride lots - Park/pool lots - Bus/carpool priority measures	- Transit passes - Bus/carpool marketing
	1D. Reduce travel delays by encouraging commuters to travel at less congested times	- Staggered or flexible working hours		
	1E. Reduce travel delays by encouraging through trips to use other routes	- Reversible lanes - One-way street systems - Signals and timing - Street and intersection geometry		

4 Action Identification Table 4: Problems at Employment Centers

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied in or near Center	Actions Applied along Approach Corridors	Actions Applied throughout Urban Area
Problem 2: High Commuting Cost or Inadequate Access to Workforce				
Lack of direct routes from residential communities	2A. Reduce peak travel times and costs by providing direct routes		- New lanes and segments - Signal coordination, timing and phasing	
Traffic congestion on routes from residential communities	2B. Reduce peak travel times by improving service quality of existing roadways		- New lanes - Signal coordination - Reversible lanes - On-street parking and loading bans	
Low service quality on alternatives to driving alone	2C. Reduce travel time and cost by providing or improving transit and carpool service	- Shuttle bus from transit stations - Carpool matching - Bicycle/moped storage - Vanpools - Employer commuting subsidies	- Expanded bus services - Transit schedule coordination - Subscription bus - Bicycle/moped lanes	- Bus transfers - Handicapped Services
Problem 3: Substandard Air Quality				
Inadequate street capacity to handle peak travel to center	3A. Reduce emissions by reducing vehicle volumes during peak hours	- Actions listed under strategies 1C and 1D.		
	3B. Reduce emissions by reducing traffic delays during peak hours	- Actions listed under strategies 1A and 1B.		
Through traffic using center streets during peak periods	3C. Reduce emissions by diverting through traffic to alternative routes	- Actions listed under strategy 1E.		
Improperly maintained vehicles	3D. Reduce vehicle emissions rates	- Spot vehicle inspections		- Bus maintenance program - Auto inspection procedures

Action Identification Table 4:
Problems at Employment Centers

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied in or near Center	Actions Applied along Approach Corridors	Actions Applied throughout Urban Area
Problem 4: Lack of Business Expansion Space				
Transportation network in or near center cannot handle additional commuter traffic	4A. Accomodate new trips by making more effective use of existing capacity	- Actions listed under strategies 1A and 1C: Reduce travel delays by making more effective use of existing capacity and by encouraging use of transit and carpools	- Actions listed under strategy 1C: Reduce travel delays by encouraging use of transit and carpools	- Actions listed under strategy 1C: Reduce travel delays by encouraging use of transit and carpools
	4B. Relocate incompatible land uses	- Loading bans		
	4C. Increase capacity of adjacent sites to support commercial development	- New lanes and segments - Street and intersection geometry - Modified bus routes - Loop/shuttle bus - Walkways - Signals and coordination - Added off-street parking - Reversible lanes - One-way streets	- Street and intersection geometry - Signals - Modified bus routes	
Problem 5: Unsafe Pedestrian Circulation				
Inadequate capacity for pedestrians →	5A. Increase capacity for walking and waiting	- Widen sidewalks and crosswalks - New walkways - Relocated bus stops - Waiting shelters		
Interference between vehicular and pedestrian traffic →	5B. Reduce conflicts between pedestrian and vehicular traffic	- Crossing design and operation - Loop/shuttle bus - New walkways or overpasses - Modified transit routes - Relocated bus stops		

4 Action Identification Table 4: Problems at Employment Centers

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied in or near Center	Actions Applied along Approach Corridors	Actions Applied throughout Urban Area
Problem 6: Commuter Parking on Residential Streets near Center				
High user cost differential between on-and off-street parking	6A. Increase user cost of parking on residential streets	- Resident permits - Time limits - Increased enforcement and fines		
Inadequate alternatives to commuting by auto	6B. Reduce travel time and user cost on alternatives modes to encourage mode shifts	- Actions listed under 1C: Reduce travel delays by encouraging commuters to use transit and carpools	- Actions listed under 1C: Reduce travel delays by encouraging commuters to use transit and carpools	- Actions listed under 1C: Reduce travel delays by encouraging commuters to use transit and carpools
Inadequate parking capacity within center	6C. Increase parking capacity within center	- Added off-street spaces - Parking space requirements for businesses - Shuttle transit from remote spaces		

Action Identification Table 5: Problems at Commercial Centers

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied in or near Center	Actions Applied along Approach Corridors	Actions Applied throughout Urban Area
Problem 1: Traffic Congestion in or near Center				
Inadequate street capacity to handle peak shopping traffic volumes	1A. Reduce travel delays by adding capacity	- New lanes - New segments - Intersection geometry		
	1B. Reduce travel delays through more effective use of existing capacity	- Signal coordination - On-street parking and loading restrictions - Expanded off-street parking and loading areas - One-way street systems - Relocated bus stops - Street and intersection goemetry - Turn lanes, signal phases or controls - Side street and curb cut closures - Parking enforcement		
	1C. Reduce traffic delays by reducing internal circulation trips by auto (including search for parking)	- Time limits and increased rates for convenient spaces - Reduced rates for remote spaces - New parking lots or garages - Shuttle transit - Covered walkways - Parcel check and pick up points		

5 Action Identification Table 5: Problems at Commercial Centers

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied in or near Center	Actions Applied along Approach Corridors	Actions Applied throughout Urban Area
Problem 2: Community Resistance to Commercial Expansion Plans				
Transportation network on or near center cannot handle increased traffic volumes	2A. Increase service quality offered by alternative modes to minimize traffic volume growth	- Shuttle buses - Covered walkways and waiting areas - Merchant delivery vans - Bicycle lanes and storage facilities - Bus lanes - Merchant shopper buses	- Expanded bus routes - Increased frequency during peak shopping hours - Community transit - Shared ride taxi - Shuttle buses from transit stations	- Expanded transit service hours - Family transit fares or passes - Revised taxi regulations
	2B. Encourage shopping trips at non-peak times			- Flexible working hours - Four day workweek - Transit fare structure
Problem 3: Crowded or Unsafe Pedestrian Circulation				
Inadequate capacity for pedestrians →	3A. Increase capacity for walking and waiting pedestrians	- Wider sidewalks - Auto-restricted zones - New walkways - Relocated bus stops - Waiting shelters - New crosswalks		
Interference between vehicular and pedestrian traffic →	3B. Reduce conflicts between pedestrian and vehicular traffic	- Crosswalk design and operation - New walkways and overpasses - Loop/shuttle buses - Modified transit routes - Relocated bus stops - Auto-restricted zones		

Action Identification Table 6: Regional, State, and National Problems

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied at Spots or Segments	Actions Applied in Corridors or in Subareas	Actions Applied throughout Urban Area
Problem 1: High Transit Operating Cost and Deficits				
	1A. Reduce operating costs by reducing vehicle-miles operated		- Modified routes and service hours	- Modified coverage, headway and service hour policies
	1B. Reduce operating costs by reducing labor requirements per vehicle-mile		- Bus priority measures - Modified routes	- Vehicle and driver scheduling procedures - Work rule changes - Fleet replacement - Management information systems
	1C. Increase revenues by raising fares			- Increased fares - Modified fare structure
	1D. Increase revenues by increasing ridership		- Modified routes - Schedule coordination - Transfer centers - Bus priority measures - Park/ride lots - Express or limited stop service - Employer pass subsidies	- Transit passes - Modified fare structure

6 Action Identification Table 6: Regional, State, and National Problems

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied at Spots or Segments	Actions Applied in Corridors or Subareas	Actions Applied throughout Urban Area
Problem 2: High Energy Consumption				
Too much energy consumed in providing personal transportation	2A. Reduce fuel consumption rate (per vehicle mile) by improving vehicle efficiency			- Vehicle inspection procedures - Reduced excise and sales taxes on new cars - Bus maintenance program
	2B. Reduce fuel consumption rate (per vehicle mile) by reducing traffic delays	- Street geometry - Revised signal operation	- Signal coordination - Flow management - Street geometry - Parking controls - Enforcement	- Revised signal location and operation standards - Right-turn-on-red standards
	2C. Reduce fuel consumption rate (per passenger mile) through incentives to use transit and carpools		- Employer pooling programs - Bus/pool priority measures on roadways - Carpool toll and parking fee reductions - Expanded bus service - Park/ride lots - Park/pool lots - Schedule coordination	- Carpool matching - Reduced transit fares - Transit passes - Carpool/transit information
	2D. Reduce fuel consumption rate (per passenger mile) through disincentives to driving alone		- Increased parking fees and tolls - Subarea entry controls	- Increased fuel taxes

Action Identification Table 6: Regional, State, and National Problems

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied at Spots or Segments	Actions Applied in Corridors or Subareas	Actions Applied throughout Urban Area
Problem 3: Vulnerability to Energy Supply Disruption				
	3A. Improve convenience of alternative modes of travel in auto-dominated markets		- Employer pooling programs - Transit schedule coordination - Bus transfer centers - Park/ride lots - Park/pool lots - Crosstown bus routes	- Carpool matching - Transit/carpool information
	3B. Prepare contingency plans to increase transit and carpool capacity for necessary urban travel			- Expanded bus operations - Bus/pool priorities - Supplementary transit
Problem 4: Unacceptable Air Quality				
Air pollutants produced by motor vehicles exceed standards	4A. Reduce emission rate (per vehicle mile) by improving vehicle efficiency		- Spot inspections - Increased enforcement of vehicle standards	- Vehicle inspections procedures - Reduced excise and sales taxes on new cars - Bus maintenance program - Increased fines for vehicle violations
	4B. Reduce emission rate (per vehicle mile) by reducing traffic delays	- Actions listed under strategy 2B: Reduce fuel consumption rate by reducing traffic delays	- Actions listed under strategy 2B: Reduce fuel consumption rate by reducing traffic delays	-Actions listed under strategy 2B: Reduce fuel consumption rate by reducing traffic delays
	4C. Reduce emission rate (per passenger mile) through incentives to using transit and carpool		- Actions listed under strategy 2C: Reduce fuel consumption rate through incentives to using transit and carpool	- Actions listed under strategy 2C: Reduce fuel consumption rate through incentives to using transit and carpool
	4D. Reduce emission-rate (per passenger mile) through disincentives to driving alone		- Actions listed under strategy 2D: Reduce fuel consumption through disincentives to driving alone	- Actions listed under strategy 2D: Reduce fuel consumption through disincentives to driving alone

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Action Identification Table 6: Regional, State, and National Problems

Underlying Transportation Deficiencies	Corrective Strategies	Actions Applied at Spots or Segments	Actions Applied in Corridors or in Subareas	Actions Applied throughout Urban Area
Problem 5: High Accident or Insurance Rates				
	5A. Reduce accident rates by improving roadway design and operations	- Intersection and segment design - Signals and phases	- Intersection and segment design - Signals and phases - Traffic flow management - Pedestrian and bicycle circulation improvements	- Rotary, grade crossing and guardrail replacement programs - Revised design signing, striping and signal standards
	5B. Reduce accident rates by improving driver behavior		- Traffic law enforcement - Signal coordination - Improved warning and informational signs	- Driver training - Revised signing, striping, and signal standards - Revised fine structure for traffic violations
	5C. Reduce accident rates by improving vehicle safety		- Actions equivalent to those listed under strategy 4A: reduce emission rates by improving vehicle efficiency	- Actions equivalent to those listed under strategy 4A: reduce emission rates by improving vehicle efficiency
Problem 6: Constrained Mobility of Non-Drivers				
Alternatives to private auto travel in many markets are unavailable, inconvenient, or expensive	6A. Increase coverage and convenience and reduce travel cost and time of alternative travel modes.		- Shared-ride taxi - Community transit - Wheelchair circulation - Bicycle/moped paths and storage - Bus transfer centers - New or modified bus routes - Waiting shelters	- Revised taxi regulations - Special transit for handicapped - Revised bus design - Discount fares and passes - Carpool matching programs

TSM Action Profiles

The strategies and actions listed in the Action Identification Tables present the range of approaches a planner might consider in developing TSM packages to solve most common problems. Some actions, however, may be inappropriate or infeasible in specific locations or for solving specific problems. The Action Profiles that follow provide applicability and effectiveness considerations for selected TSM actions. This information, combined with a knowledge of local conditions, can be used to further screen candidate actions prior to initiating analysis and design activities.

The actions covered by the Profiles are listed on the following pages, where they are grouped by location or scale of implementation. Not all of the actions listed in the Identification Tables are covered; the emphasis is on local, suburban, and corridor actions that are outside the experience of transportation agencies in many small to medium-sized urban areas, yet may be applicable to their problems.

The Profiles provide the following information about each action:

1. A brief description of the action that indicates how it is usually intended to work.

2. A list of the problems that commonly would be addressed by the action, providing a check back to the action identification tables to confirm the action's appropriateness.

3. A description of the land use and transportation conditions that typically affect the action's feasibility or effectiveness, along with an assessment of the condition's importance.

4. Issues that should be considered in designing, implementing, and operating the action, and problems that might arise in its implementation or operation.

5. A list of factors that often are appropriate for assessing the action along with specific performance and impact measures and, in some cases, ranges of observed values.

6. References to reports, manuals, or articles that provide more detailed information on the action's feasibility or effectiveness and describe examples of the action's implementation.

The information is organized for sequential application in screening a proposed action, i.e., a user proceeds through a profile sheet and retains the action as a candidate as long as it remains appropriate, feasible, and potentially effective.

The first two items confirm the general applicability of the action to the problem. The third item contains specific "conditions for application" that ideally should be present at the site or created by implementing other actions. For example, concentrated employment, regular work hours and long commutes are conditions that will contribute to the success of a proposed vanpool program. Some conditions are almost mandatory and affect the action's feasibility. For example, adequate capacity and connectivity on adjacent streets should be present if converting an important artery to a pedestrian or transit mall is proposed. If any required conditions are not present and cannot be developed by implementing other actions, the proposed action generally should be discarded as infeasible. Most applicability conditions are looser, but an action is unlikely to be effective unless one or two or those listed are present.

The "design and operational considerations" or "potential implementation problems" provide a secondary test of feasibility by indicating impacts that might block the action's implementation if not remedied by careful design, involving other agencies in planning the action, or by developing supporting actions. Examples are laws or ordinances that prevent shared-ride taxi service, traffic engineering and signal improvements needed to smoothly merge traffic flows at the ends of a one-way street pair, and increased enforcement to control use of ramp meter bypasses.

Only when the proposed action has cleared these hurdles should the user review the referenced literature to obtain more information about the action, or begin design and analysis activities. The "potential evaluation factors" listed in the profiles contain both qualitative and quantitative factors that might be important in evaluating an action, and are included to help set up an efficient design and analysis effort; they are not to be taken as lists of measures that must be estimated under all circumstances. The Impact Estimation Aids section of the Handbook contains guidelines on when and how different factors should be used in analysis and evaluation.

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  19. Two-Way Left-Turn Lanes
  21. Signal Phases for Left Turns
  22. Reroute Turning Traffic

- Actions Applied along Arterial Street Corridors

  7. Park-and-Ride Lots Along Transit Routes
  8. On-Street Parking Bans During Peak Periods
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  18. Reversible Lanes
  19. Two-Way Left-Turn Lanes
  20. New Street Segments
  21. Signal Phases for Left Turns
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- Actions Applied in Employment Centers

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  2 Flexible Working Hours
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- Actions Applied in Residential Neighborhoods

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- Actions Applied Region-Wide

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  36. Elderly/Handicapped Paratransit Service Brokerage

Profile 1: Staggered Work Hours

Sharp travel peaks and periods of congestion may occur on streets and transit routes serving an employment center if many employees are on common work schedules (e.g., 8:00 and 8:30 arrivals). By staggering the work schedules of firms or of sections of larger firms in the center (e.g., by having some employees start work at 7:45, 8:15, or 8:45), commuting trips to and from the center can be spread more evenly over acceptable commuting hours, with resulting decreases in congestion levels during peak periods.

Problems Addressed:

- Traffic congestion consistently develops during peak commuting periods in or near an employment center.
- Congestion is expected to increase if business expansion plans are approved and implemented.
- Transit vehicles serving an employment center are consistently overcrowded during parts or all of the peak commuting periods.

Conditions for Application:

- Slack capacity - Fifteen- to thirty-minute per'ods of relatively low traffic should be consistently observable within the "acceptable hours" over which work trips are to be staggered. These periods may be within the existing peaks or on their shoulders. The action will not be effective if congestion is fairly uniform during acceptable commuting hours or occurs randomly as a result of factors outside the employment center.
- Employment concentration - Unless the action is being implemented to relieve congestion on internal streets or immediate access roads, the center should contain, as a general guideline, at least 40% of the employment in a 1- to 2-mile radius. Without this concentration of employment, rescheduling the center's employees is unlikely to have a significant effect on congestion levels on the surrounding street (or transit) network.
- Large firms - Staggering work hours within one or more large firms or government agencies (1000 or more employees) in the center may be sufficient to solve the congestion problem and is probably easier than staggering the hours of several small firms.
- Transit availability - Transit routes serving the center should have trips convenient to all common work schedules, otherwise some employees commuting by transit may be unable to reach their jobs if their work schedules are changed.

Potential Implementation Problems:

- Not all businesses and labor organizations will be willing to cooperate.
- Some carpools and vanpools may disband if riders whose schedules are shifted cannot be replaced.

Potential Evaluation Factors:

- Time shifts of users (the means of accomplishing other objectives):
  - change in passenger or vehicle volumes entering (AM) or leaving (PM) employment center during each 10- to 20-minute interval of peak periods (5% to 15% volume reductions during peak intervals are likely in a major center with several employers, and higher reductions are possible to achieve near large plants)
- Congestion reduction:
  - change in peak operating speeds or levels-of-service on key streets or highway segments in or near the center
- Transit crowding:
  - change in average loads or load factors on transit routes entering (AM) or leaving (PM) the center
- Transit operations:
  - change in operating and maintenance costs on transit routes serving center
  - change in ridership and revenues on transit routes serving center

References:

(1) Port Authority of New York and New Jersey, Staggered Work Hours Study: Design and Implementation of Staggered Work Hours in Manhattan, Volume II: Technical Report (August 1977) 400 pp., NTIS No. PB-298938.

(2) Wagner, F.A., "Alternative Work Schedules: Impacts on Transportation," NCHRP Synthesis of Highway Practice 73, Washington DC (November 1980) 54 pp.

Contains descriptions and impacts of programs for government employees in Ottawa and Toronto that combine staggered and flexible hours, and summarizes the findings of reference 1.

2 Profile 2: Flexible Working Hours

Fixed work schedules in an employment center often contribute to congestion levels on roads and transit routes used by commuters and hinder the ability of employees (or potential employees) to arrange family or neighborhood-based carpools. By allowing employees flexibility in their work arrival and departure times, individuals can arrange their commuting schedules to avoid congestion peaks and coordinate travel with family and neighbors.

Problems Addressed:

- Traffic congestion consistently develops during peak commuting periods in or near an employment center.
- Congestion is expected to increase if business expansion plans are approved and implemented.
- Transit vehicles serving an employment center are consistently overcrowded during parts or all of the peak commuting periods.
- Inexpensive transportation is not available to employees or potential employees under current work schedules.

Conditions for Application:

- Slack capacity - If the action is implemented to reduce existing congestion peaks on streets or transit vehicles, intervals with lower traffic density should exist during acceptable flex-time commuting periods. In general, the flex-time commuting period must be longer than the current commuting peak if the action is to be effective.
- Transit availability - If transit is used by 20% or more of the employees, service should operate near peak frequency throughout the flex-time commuting period.
- Employment concentration - As a general guideline, the center should contain at least 40% of the employment in a 1- to 2-mile radius if schedule flexibility is to have a significant effect on congestion levels on the surrounding street (or transit) network.
- Large firms - Flexible work hours at one or more large firms or agencies (1000 employees or more) may be sufficient to solve the congestion problem, and may be easier than gaining the cooperation of several smaller firms.

Potential Implementation Problems:

- The cooperation of businesses may be difficult to obtain, particularly those with assembly lines or other processes requiring the coordination of employees' work hours.

Potential Evaluation Factors:

- Time shifts of users (the means of accomplishing other objectives):
    - change in passenger or vehicle volumes entering (AM) or leaving (PM) the employment center during each 30-minute interval of peak period (5% to 15% volume reductions are likely during peak intervals)
- Congestion reduction:
    - change in peak operating speeds or levels-of-service on key streets or highway segments in or near the center
- Transit crowding:
    - change in average loads or load factors on transit routes entering (AM) or leaving (PM) the center
- Transit operations:
    - change in operating and maintenance costs on transit routes serving center
    - change in ridership revenues on transit routes serving center

References:

(1) Wagner, F.A., "Alternative Work Schedules: Impacts on Transportation", NCHRP Synthesis of Highway Practice 73, Washington DC (November 1980) 54 pp.

Presents travel and traffic peaking characteristics, and the impacts of alternative work schedules on these characteristics reported in several evaluation studies. Examples include programs for government employees in Ottawa, Toronto and Washington DC.

(2) Barton-Aschman Assoc., Inc., Traveler Response to Transportation System Changes, Second Edition, prepared for USDOT/FHWA, Office of Highway Planning, Contract No. DOT-FH-11-9579 (July 1981) 400 pp.

Presents options and summarizes results reported for programs instituted in Ottawa, San Francisco and New York.

Profile 3: Increased Peak Period Roadway, Bridge, or Tunnel Tolls

Tolls are collected on major commuter routes in some urban areas. An increase, at least during peak periods, acts as an incentive for commuters to form carpools or use transit, thereby reducing the number of vehicles and travel times on the route. Peak period increases also may encourage some travelers to shift their trips to less-congested time periods or routes. The action may be used on weekends or holidays to encourage transit use and ridesharing for trips to beaches and other recreational areas.

Problems Addressed:

- During peak commuting periods, traffic congestion is prevalent on a toll facility or near the workplaces of commuters using the facility.
- Air pollutant concentrations that develop along the facility's corridor or near workplaces of commuters using the corridor can be attributed to traffic volumes and flow conditions.

Conditions for Application:

- Revenue maintenance - A base level of toll income usually is required to cover facility operating, maintenance, and debt service costs. Large diversions to other modes or facilities may occur if the toll increase is very large or if slack capacity exists on parallel facilities. Such diversions may jeopardize basic revenue requirements, despite the increased fees collected from remaining users.
- Traffic composition - A toll increase will probably have little impact on the timing of long-distance trips passing through the region, so its effect on congestion will be larger if peak period traffic consists primarily of intra-regional travelers.
- Transit availability - The action will be more effective if express transit service, park/ride and park/pool lots are available to commuters using toll facility.

Potential Implementation Problems:

- Increased traffic enforcement may be necessary to avoid safety and flow problems at the transition to and from peak period toll rates.
- Commuters and local businesses shipping goods during peak periods may oppose the increase.

Potential Evaluation Factors:

- Time, mode, or route shifts of users (the means of accomplishing other objectives):
  - changes in hourly vehicle volumes on facility during peak and shoulder periods (observed elasticities range from -0.13 to -0.29, and depend on the availability of alternate free routes; -.2 is a good value for initial planning purposes)
  - changes in hourly vehicle volumes on parallel facilities during peak and shoulder periods
- Congestion reduction:
  - change in peak operating speeds on facility, on parallel facilities, and/or on key streets in employment centers served by the corridor
- Air quality:
  - change in air pollutant emissions during peak periods along key portions of corridor and/or in employment centers
- Facility operations:
  - change in toll revenues
  - change in toll collection costs
- Transit operations:
  - change in operating and maintenance costs on corridor transit routes
  - change in ridership and revenues on corridor transit routes

References:

- Kulash, Damian, Congestion Pricing A Research Summary, (The Urban Institute) July 1974.

Examples:

- Port Authority of New York and New Jersey, Trans-Hudson Crossings
- East-West Expressway, Miami, FL

4

Profile 4: Toll Discounts for Carpools During Peak Periods

Tolls are collected on major commuter routes in some urban areas. Reduction in daily, weekly, or monthly tolls charged to vanpool or carpool drivers provides an incentive for commuters to form pools, thereby reducing the number of vehicles and travel time along the route. The action also may divert carpools and vanpools onto the toll facility, thereby reducing congestion on parallel facilities.

Problems Addressed:

- During peak commuting periods, traffic congestion is prevalent on a toll facility, its corridor, or near the workplaces of commuters using the facility.
- Air pollutant concentrations along the facility's corridor or near the workplaces of commuters using the corridor can be attributed to traffic volumes and flow conditions.

Conditions for Application:

- Revenue maintenance - A base level of toll income usually is required to cover facility operating, maintenance, and debt service costs. Total revenues must not fall below this limit as a result of the discounts.
- Ridesharing potential - Employment concentrations, high parking costs and large firms all make ridesharing attractive and convenient. The action will not be effective if users of the facility lack good opportunities to form carpools.
- Commuter dominance - If the discount is to be effective in reducing congestion, peak period traffic on the toll facility should consist primarily of commuters. Also, opposition may develop if vacationers and other non-commuters are seen as being major beneficiaries of the discount.
- Limited transit service - If most commuter markets in the corridor are well served by transit, the action may divert more transit riders than auto drivers into carpools, minimizing the impact on congestion levels while decreasing transit revenue.
- Toll booth operation - Time spent at toll booths (including waiting) by discount users should not exceed time spent by "exact-change lane" users not claiming discount. At many plazas, additional booths will have to be manned to meet this condition, with a resulting increase in operating costs.

Potential Implementation Problems:

- Increased weaving on approaches to toll booths may develop if "carpool only" booths are used without designated approach lanes.

Potential Evaluation Factors:

- Mode or route shifts of users (the means of accomplishing other objectives):
    - change in hourly vehicle volumes on facility during peak and shoulder periods (up to 5% reduction in peak volume might be achieved)
    - change in hourly vehicle volumes on parallel facilities during peak and shoulder periods
- Congestion reduction:
    - change in peak operating speeds on facility, or parallel facilities and/or on key streets in employment centers served by facility
- Air quality:
    - change in air pollutant emissions during peak periods along key portions of corridor and/or in employment centers
- Facility operations:
    - plaza modification costs
    - change in toll revenues
    - change in toll collection costs
- Transit operations:
    - change in operating and maintenance costs on corridor transit routes
    - change in ridership and revenues on corridor transit routes

References:

(1) Barton-Aschman Assoc., Inc., Traveler Response to Transportation system Changes, Second Edition, prepared for USDOT/FHWA, Office of Highway Planning, Contract No. DOT-FH-11-9579 (July 1981) 400 pp.

Presents a brief summary of the elimination of tolls for buses and 3+ carpools on the San Francisco/Oakland Bay Bridge.

References (Cont'd):

(2) Rothenberg, M.J. and D.R. Samdahl, JHK and Associates, Priority Treatment of High Occupancy Vehicles, USDOT report No. FHWA/RD-80/062 (January 1981) 125 pp., NTIS # PB81-216582.

Summarizes the travel time and volume impacts of reduced tolls on the Connecticut Turnpike and Hudson River Crossings into New York City.

5

Profile 5: Residential Parking Permits

Residential streets near employment centers or transit stations are a source of free and often convenient parking for commuters. Their cars inconvenience residents who must park on the street, and may create a hazard for neighborhood children. One solution is to sign neighborhood streets for residents' parking only and issue windshield stickers or dashboard placards to residents.

Problems Addressed:

- Commuters usurp parking spaces along residential streets.
- Commuters searching for parking on residential streets create a safety hazard and degrade the residential quality of a neighborhood.

Conditions for Application:

- Residential density - The action is most beneficial in neighborhoods that have a high residential density (typically over 15,000 persons per square mile) and only limited off-street parking.
- Alternatives for commuters - Good transit service should be available to commuters currently parking on local streets, or slack parking capacity should exist within the employment centers to which the commuters are traveling.
- Segregated land uses - If residential blocks have many business, commercial or professional operations that require on-street parking for clients, the parking plan may become complicated and difficult to establish and enforce.

Potential Implementation Problems:

- Ticketing and towing illegally parked cars may have to be increased to establish and enforce program.
- Provisions are needed for vehicles of visitors, medical personnel, repairmen, and other people requiring access to residences.
- Provisions are needed for clients and employees of commercial activities in the neighborhood.

Potential Evaluation Factors:

- Parking availability in neighborhood:
  - occupancy of on-street parking spaces during weekdays (rates of 100% or higher before implementation have been reduced to anywhere from 40% to 95% depending on land use and the design and operation of the action)
- Street use:
  - change in vehicles entering neighborhood during morning commuting hours

Potential Evaluation Factors: (Cont'd.)

- Action administration:
  - revenues from fees and fines
  - administrative and enforcement costs
  - sign installation and maintenance costs
- Transit operations:
  - change in ridership and revenues on transit routes to employment center
- Parking operations:
  - change in parking revenues in and near employment center
  - change in occupancy rate of parking spaces in and near employment center

References:

(1) Olsson M., and G. Miller, The Impact on Commuters of a Resident Parking Permit Program, The Urban Institute, Washington DC (December 1979), 30 pp.

Describes the planning, implementation and evaluation of a residential permit program in Alexandria VA.

(2) Peat, Marwick, Mitchell and Co., "Study of Parking Management Tactics: Volume 2: Overview and Case Studies," Report No. FHWA-PL-79-021 (December 1979) 237 pp.

Discusses the implementation and operation of permit programs, and tabulates the characteristics of programs in 11 cities. Case studies of overall parking management program describes permit parking in Arlington County (VA), Boston (MA), Montgomery County (MD) and San Francisco (CA).

(3) Simkowitz, H., L. Heder and E. Barber, "The Restraint of the Automobile in American Residential Neighborhoods," UMTA/TSC Project Evaluation Series, Report No. UMTA-MA-06-0049-78-3 (May 1978) 64 pp.

Discusses design and legal issues in implementing a permit program, and present case study descriptions of programs in Cambridge (MA), San Francisco (CA) and Washington (DC). An appendix summarizes the parking policies of forty communities.

Profile 6: Neighborhood Traffic Barriers

Grid streets and other open street patterns allow motorists to use residential streets to avoid traffic lights and bottle-necks on arterial streets. The added traffic and, in many cases, excessive speeds are a hazard to neighborhood residents and may degrade the quality of the neighborhood. A variety of barriers may be erected to create cul-de-sacs or to limit through or turning movements at intersections. Narrowing streets at intersections with arteries and other partial barriers may be used to visually block the use of neighborhood streets. Stop signs and one-way streets may also be used to discourage through traffic.

Problems Addressed:

- Through traffic on residential streets creates safety hazard and/or degrades residential quality of neighborhood.

Conditions for Application:

- Emergency access - All buildings must remain accessible to fire engines and other emergency vehicles.
- Arterial service - Arterial streets bordering neighborhood should have slack capacity and serve all traffic flows.

Potential Implementation Problems:

- Barriers may impede neighborhood circulation and services such as mail delivery and garbage collection, so routes for those vehicles should be considered in developing a barrier plan.
- Traffic controls (such as stop and turn prohibition signs) and partial barriers may be difficult to enforce.
- A complex circulation system that is confusing to residents will be difficult to implement and enforce.
- Residents may object to the appearance of low-cost barriers.

Potential Evaluation Factors:

- Neighborhood streets:
  - change in traffic volume entering neighborhood (reductions may range from 10% to 60% depending on design and local conditions)
  - change in the number of straight routes through neighborhood
  - change in vehicle speeds
  - change in safety or accidents

Potential Evaluation Factors: (Cont'd.)

- Arterial streets:
  - change in operating speeds or levels-of-service on key sections of adjacent arterial streets
- Action costs:
  - installation costs
  - annual maintenance costs
  - change in enforcement costs
- Neighborhood service:
  - change in tour distance of routine delivery and service vehicles

References:

(1) Simkowitz, H., L. Heder and E. Barber, "The Restraint of the Automobile in American Residential Neighborhoods," UMTA/TSC Project Evaluation Series, Report No. UMTA-MA-06-0049-78-3 (May 1978) 64 pp.

Describes different types of barriers and tabulates their use in 37 communities. Case studies discuss neighborhood barrier packages implemented in Berkeley (CA) and Seattle (WA).

(2) Wynne, G. (editor), Traffic Restraints in Residential Neighborhoods, Transaction Books, Rutgers University, New Brunswick NJ (1980).

(3) Dalby, E., Transportation and Road Research Laboratory, "Area-Wide Measures in Urban Road Safety", TRRL Supplementary Report 517, Crowthorne, U.K. (1979) 21 pp., NTIS # PB80-158959.

Discusses action as means of addressing community-wide accident problems, and presents before-after data from small English cities.

7

Profile 7: Park-and-Ride Lots Along Transit Routes

Transit routes operating in low density suburbs seldom can draw sufficient patronage from walk-ons to meet system-wide productivity standards, and circuitous street patterns further hinder their operation. Strategically located park-and-ride lots can vastly expand a route's drawing area and increase its ridership while limiting its operation to arterial streets and expressways.

Problems Addressed:

- Traffic congestion consistently develops along corridor or in major employment centers served by corridor during peak commuting periods.
- Air pollutant concentrations consistently develop along corridor or in major employment centers served by corridor during peak commuting periods.
- Local transit routes operated in low density areas to meet regional service requirements do not meet productivity or cost recovery standards.

Conditions for Application:

- Convenient sites - Lots are best located adjacent to arterial streets serving the intended drawing areas. Circuitous access routes will make the overall transit trip less attractive, reducing the desired mode shift. In addition, resident opposition is likely if traffic increases on residential streets near the lots.
- Direct transit routing - Buses should not have to detour far from their principal route to serve the lots. Detours increase bus operating costs and travel time, and the time increase will lower the potential mode shift.
- Auto availability - Prospective lot patrons must have access to autos for their commutes, so the action will be most attractive in areas with high auto ownership rates.
- Long commuting trips - As a general rule, park-and-ride lots should be at least 4 miles from the major employment centers served by the transit route. The major exceptions are interceptor lots along high frequency bus or rail lines serving the central business district.
- Poor auto service quality - The potential for mode shift is greater if highways in the corridor operate at level-of-service or worse and if parking costs are high in the employment centers served by the transit route.

Conditions for Application (Cont'd.):

- Good transit service quality - Transit routes serving the lots should operate reliably on schedules convenient to commuters traveling to the major employment centers in the corridor, and ideally should require prospective patrons to leave home no earlier than for their current commutes by auto.
- Safety and Security - Patrons will not be attracted to the lots if they seem unsafe for themselves or their vehicles.

Design and Operational Considerations:

- Convenient sites may be expensive or difficult to acquire, so the leasing of church, drive-in theatre, or other parking sites not used during standard working hours might be considered until sufficient patronage is established to justify a larger investment.
- Lots near residences may require fencing and landscaping for acceptance by the community.
- Good lighting and clear sight lines will help users, police and others maintain the safe operation of the lots.
- Transit deficits will increase if most lot users are diverted from parallel bus routes that continue to operate.

Potential Evaluation Factors:

- Mode shift (to accomplish other objectives):
  - door-to-door travel times and out-of-pocket costs for park-and-ride trips from drawing areas to major employment centers served by the transit route(s) during peak commuting hours (5- to 20-minute savings possible depending on location, service design and existing service quality)
  - travel times and out-of-pocket costs for corresponding auto trips
  - change in transit ridership on park-and-ride and parallel routes
  - change in vehicle volumes on key street segments in corridor or employment centers during peak commuting periods

Potential Evaluation Factors: (Cont'd.)

- Congestion reduction:
  - change in peak operating speeds or levels-of-service on key highway sections in corridor and/or in employment centers
- Air quality:
  - change in air pollutant emissions during peak period along key highway sections and/or in employment centers
- Transit cost recovery:
  - change in transit revenues on park-and-ride and parallel routes
  - change in annual transit operating costs on park-and-ride and parallel routes
- Lot operations:
  - development cost of park-and-ride lots
  - annual operating and maintenance costs of lots

References:

(1) Peat, Marwick, Mitchell and Co., "Study of Parking Management Tactics," Volume 2: "Overview and Case Studies," Report No. FHWA-PL-79-021, (December 1979) 237 pp.

Case studies for Baltimore MD, Portland OR and Seattle WA briefly describe park and ride policies and operating experience.

(2) Levinson, H.S., C.L. Adams and W.F. Hoey, "Bus Use of Highways - Planning and Design Guidelines," NCHRP Report No. 155, Transportation Research Board, Washington DC (1975) 160 pp.

Presents typical layouts and design guidelines.

References: (Cont'd.)

(3) Barton-Aschman Assoc., Inc., Traveler Response to Transportation System Changes, Second Edition, prepared for USDOT/FHWA, Office of Highway Planning Contract No. DOT-FH-11-9579 (July 1981) 400 pp.

Discusses the use and mode choice aspects of park-and-ride lots along bus and rail routes on several cities, including Milwaukee, Hartford, Atlanta, Miami and Seattle.

8

Profile 8: On-Street Parking Bans During Peak Periods

Curb lanes designated for parking can provide an inexpensive resource for increasing a street's traffic carrying capacity, particularly if periods of heavy traffic flow do not overlap with periods of high parking use. Parking bans near intersections also can provide space for turning lanes or additional through lanes, increasing an intersection's capacity.

Problems Addressed:

- Traffic congestion consistently develops in an employment center or along an arterial street during peak travel periods.
- Delays at intersections contribute to air pollutant concentrations in excess of standards.

Conditions for Application:

- Absence of high-turnover, high-occupancy parking - Commercial establishments such as newsstands, dry cleaners, drug stores, and convenience stores are patronized by people making quick stops on their way to or from work. Unless very convenient parking is available to patrons of these stores, either off-street or along side streets, a curb parking ban will be difficult to enforce and will be strongly opposed by store owners.
- Absence of other curb uses - The use of the curb lane by buses, taxis or autos stopped to pick up or discharge passengers, or by truck loading or unloading goods will lower its capacity for moving vehicles. If the curb lane currently is heavily used for these purposes, a parking ban will likely be ineffective unless other controls are established, such as a loading ban or a bus-only operation.
- Space for turning movements - The curb lane is part of the turning radius normally available to cars turning into or out of the right-hand travel lane. If turning volumes are high and turning movements are hampered by reduced radii, the capacity added by the new lane may be minimal, and accidents may increase.
- Pedestrian buffer - Cars parked in the curb lane provide a buffer between pedestrians and vehicular traffic. If the curb directly abuts a narrow or heavily-used sidewalk, the use of the curb lane by moving vehicles may present a hazard to pedestrians.

Potential Evaluation Factors:

- Congestion reduction:
  - change in average travel speed or level-of-service along streets affected by the action, including parallel arteries on which parking is not restricted (5% to 20% improvement possible depending on existing congestion and midblock interference levels)
- Street operations:
  - signing and other implementation costs
  - change in parking enforcement costs
  - change in parking revenues, including fines
- Commercial activity:
  - change in sales of commercial establishments along street
  - change in number of patrons entering stores during hours of parking ban
- Transit operations:
  - change in operating costs of transit routes serving the corridor or center

References:

(1) D.C. Department of Transportation, Metropolitan Police Department, Office of the Corporation Counsel, "Improved Parking and Traffic Enforcement in the District of Columbia" (April 1977) 45 pp.

(2) Peat, Marwick, Mitchell and Company, "Study of Parking Management Tactics, Volume 2: Overview and Case Studies," Report No. FHWA-PL-79- 021 (December 1979) 237 pp.

Boston MA case study discusses a peak period ban in the downtown.

(3) Pontier, W.E., P.W. Miller and W.H. Kraft, Edwards and Kelcey, Inc., "Optimizing Flow or Existing Street Networks", NCHRP Report 113, Washington DC (1971) 414 pp.

Presents a "before-after" analysis of parking restrictions near intersections in Louisville (KY) and Newark (NJ).

Profile 9: Parking Reserved for Short-Term Use

Commuters and other all-day visitors usually arrive at an activity center before shoppers and other part-time visitors, and consequently will tend to occupy the most convenient spaces. If capacity is limited, few spaces may remain for short-term users. Several measures can be taken to reserve spaces for short-term users; these include on-street parking bans during the peak, metered parking with enforced time limits, the designation of off-street facilities (or portions of those facilities) for short-term use, and the closure of certain spaces until the end of morning commuting period. Peak traffic congestion problems also may be alleviated by reducing the number of spaces available to commuters.

Problems Addressed:

- All-day parkers leave insufficient spaces for shoppers and other short-term visitors to an employment, commercial, or institutional center.
- Declining retail sales can be attributed to inadequate access by shoppers.
- Traffic congestion consistently develops in or near the center during peak commuting periods.

Conditions for Application:

- Revenue maintenance - Total parking revenues should not decline below the amount required for debt service and facility operations and maintenance. All-day rates may have to be raised if revenues from reserved spaces do not match their previous income as all-day spaces.
- Transit availability - A limit on commuter parking will be easier to impose, and less likely to cause problems in adjacent residential neighborhoods, if good transit service is available to most commuters.
- Midday parking constraints - Full lots and garages, 80% or higher occupancy of on-street spaces, double parking, and drivers cruising for parking are good indications that inadequate parking is available during the day for short-term users.

Potential Implementation Problems:

- The action may require increased and visible enforcement, and simple restrictions and clear signs will help this effort.

Potential Evaluation Factors:

- Off-peak parking availability:
  - change in percent or number of spaces unoccupied at the end of the morning commuting period

Potential Evaluation Factors (Cont'd.):

- Commercial activity:
  - change in number of people entering center during the day
  - change in retail sales in center
- Congestion reduction:
  - change in number of vehicles entering center during the morning commuting period
  - change in peak operating speeds or levels-of-service on key sections or intersections in center
- Parking operations:
  - change in parking revenues during peak and midday periods
  - change in operating and enforcement costs
- Transit operations:
  - change in ridership and revenues on routes serving center during peak and midday periods

References:

(1) Peat, Marwick, Mitchell and Co., "A Study of Parking Management Tactics," Volume 2: "Overview and Case Studies," Report No. FHWA-PL-79-021 (December 1979) 237 pp.

The case studies discuss some examples, including a 7 to 9:30 AM on-street ban in downtown Boston (MA), the sale of a limited number of employee parking permits in Eugene (OR), and short-term garages in downtown Portland (OR).

Other Examples:

- Boston, MA, under common garage (designated spaces not opened till 10 a.m. for short-term use)

10

Profile 10: Increased Parking Rates

Parking rates provide a relatively direct means of regulating the amount of vehicular traffic in a major activity center. An increase in rates will encourage travelers to share rides to reduce an individual's costs, or to use transit. If the increase is limited to all-day rates, the action may free spaces for shoppers and visitors. If rates in commercial lots and garages are not directly regulated, a municipal tax or surcharge may provide an indirect means of increasing routes at those facilities.

Problems Addressed:

- Traffic congestion consistently develops on or near the center during peak travel hours.
- Air pollutant concentrations develop in or near the center during peak travel hours.
- All-day parkers leave insufficient spaces for shoppers and other short-term visitors to center.
- Street capacity in or near the center is insufficient to handle traffic volumes expected if business expansion plans are implemented.

Conditions for Application:

- Revenue maintenance - Parking revenues are used to cover the costs of debt service and facility operations and maintenance. Patronage loss may be high if the increase is large or if less expensive parking exists or can be developed near the center, and the resulting revenue loss may reduce income below minimal requirements despite increased fees collected from remaining users.
- Transit availability - The action will be more effective in reducing vehicle trips if good transit service is available to most employees working in the center.
- High parking occupancy rate - In the absence of business expansion plans, no more than 15% of off-street, all-day spaces should be vacant in a major employment center at the end of the morning commuting peak if the action is to appear justified.

Potential Implementation Problems:

- Businesses may oppose the increase as limiting their ability to attract employees or customers.
- Garage and lot owners and users probably will oppose the increase.
- Residents of nearby neighborhoods may object to the increase if center users shift to parking on their streets.

Potential Evaluation Factors:

- Mode shift (the means of accomplishing other objectives):
  - change in vehicle volumes entering the center during the morning commuting period (elasticity to parking rates may vary from -.05 to -.30 depending on employer parking subsidies and the availability of transit and carpooling for commuting trips)
- Congestion reduction:
  - changes in peak operating speeds or levels-of-service on key sections and intersections in center
- Off-peak parking availability:
  - changes in percent or number of spaces unoccupied at the end of morning commuting period
- Air quality:
  - change in air pollutant emissions in center during peak commuting periods
- Parking operations:
  - change in parking revenues during peak and midday periods
- Transit operations:
  - change in ridership and revenues on transit routes serving center during peak and midday periods
- Commercial activity:
  - change in number of people entering center during the day
  - change in retail sales in center

10

References:

(1) Peat, Marwick, Mitchell and Co., "Study of Parking Management Tactics," Volume 2: "Overview and Case Studies", Report No. FHWA-PL-79-021, (December 1979) 237 pp.

Discusses pricing options, and tabulates measures enacted in 9 communities along with selected results. One of the case studies presented (San Francisco CA) included an increase in monthly parking rates.

(2) Kunze, R., C. Heramb and T. Martin, "Impacts of Municipal Parking Fee Increases in Downtown Chicago", Transportation Research Record 786, Washington DC (1980) pp. 21-30.

Discusses the impacts of a fee increase at municipal garages in which all-day and monthly rates were doubled and hourly rates where raised by 30-40%.

(3) Pickrell, D. and D. Shoup, "Employer Subsidized Parking and Travel Mode Choice", Transportation Research Record 786, Washington DC (1980) pp. 30-39.

Compares the mode choices of commuters with and without parking subsidies, and summarizes the changes that occured in Ottawa when the Canadian government began charging employees for using parking spaces.

11

Profile 11: Parking Rate, Fine, and Time Limit Adjustments

Some parking spaces within an activity center usually are much more convenient to commercial and business establishments than others. If parking fees, fines, and time limits do not reflect the relative quality of parking spaces, illegal parking and congestion are likely in the most densely developed parts of the center. This action can be applied to shift users to less-convenient and underused facilities.

Problems Addressed:

- Drivers add to traffic congestion by double parking, or by searching or queuing for spaces convenient to stores.

Conditions for Application:

- Low turnover rate - Turnover of spaces convenient to commercial establishments is under six per day, or average use is longer than an hour.
- Illegal parking or stopping - Cars illegally parked or idling on streets near stores may indicate that convenient parking is underpriced or that remote parking is overpriced.
- Availability of longer-term parking - Compliance with higher rates or stricter time limits will be higher if 1- to 4-hour parking is available within 800 feet of most commercial establishments.

Potential Implementation Problems:

- Parking enforcement efforts may have to increase to establish compliance with new rates and limits. Increased fines, however, may cover the added costs.
- Merchants probably will object to higher rates, and may object to stricter time limits or enforcement as hurting business. Consequently, rate reductions for remote spaces may have to be implemented as part of an adjustment plan.

Potential Evaluation Factors:

- Parking availability and use:
  - changes in occupancy rates of parking spaces in different parts of the center
  - change in number of illegally parked or stopped cars in center
- Parking operations:
  - change in parking revenues
  - change in parking fine receipts
  - change in parking enforcement costs

References:

(1) Peat, Marwick, Mitchell & Co., "A Study of Parking Management Tactics," Volume 2: "Overview and Case Studies", Report No. FHWA-PL-79-021. (December 1979) 237pp.

Discusses pricing and enforcement tactics used in several communities. Case study presentations include pricing differentials in Silver Spring MD and increased time limit enforcement in Boston MA, Portland OR and Washington DC.

Profile 12: Expanded Off-Street Parking

Off-street parking can be added in many employment, commercial, institutional or town centers using vacant land or as part of a redevelopment or expansion project.

Problems Addressed:

- High occupancy rate of existing parking is discouraging shoppers or business expansion plans.
- People using the center are parking on adjacent residential streets.
- A reduction in on-street space, proposed to meet transportation or other objectives, is expected to limit the availability of parking.

Conditions for Application:

- Adequate street capacity - Sufficient capacity should exist on streets in and near the center to handle users of the new spaces at acceptable service levels.
- Limited transit service - If transit service is available from much of the center's market area, increased parking may divert riders and reduce transit revenues.
- High parking occupancy - Parking occupancy throughout the center should exceed 85% of capacity. If less, new facilities may be underused of divert patrons and revenues from less convenient facilities.

Potential Implementation Problems:

- Time limits or other measures may be needed to prevent employees or other all-day users from parking in the new spaces.
- Available sites for new spaces may be beyond the acceptable walking distance of many shoppers.
- New lots or garages may hinder pedestrian access from adjacent neighborhoods.
- Diversions of patrons to private auto may reduce transit or taxi revenues.

Potential Evaluation Factors:

- Parking availability and use:
  - change in parking space occupancy rate
  - change in number of illegally parked or stopped cars

Potential Evaluation Factors (Cont'd.):

  - change in number of vehicles parking in center per day
- Commercial activity:
  - change in number of people entering center
  - change in retail sales
- Parking operations:
  - change in parking revenues
  - change in operating, maintenance, and enforcement costs
  - construction costs, including street modifications
- Transit and taxi operations:
  - change in transit ridership and revenues
  - change in taxi patronage and revenues
- Street operations:
  - change in vehicle volume entering center
  - change in operating speeds or levels-of-service on key streets in center

References:

(1) Peat, Marwick, Mitchell & Co., "A Study of Parking Management Tactics," Volume 2: "Overview and Case Studies," Report No. FHWA-PL-79-021 (December 1979) 237 pp.

Case study on Portland OR includes new downtown garages for short-term users.

13

Profile 13: Freeway Ramp Control

Traffic signals and other control devices can be placed on freeway ramps to meter the flow of vehicles onto the facility, thereby improving traffic flow and reducing congestion. The control devices can be pretimed to limit the number of vehicles using a ramp during peak travel periods, actuated by freeway traffic volumes near the ramp, or tied into a central control system that monitors flow conditions at key points along the freeway.

<u>Problems Addressed</u>:

- Traffic congestion consistently develops on the freeway during peak travel periods.
- Air pollutant concentrations in excess of standards consistently develop near the freeway as a result of congested traffic flow.

<u>Conditions for Application</u>:

- <u>Adequate storage capacity</u> - Queues will form at most ramp controls during peak periods. Unless adequate storage capacity is available on the ramp, the queues will extend onto access roads and adjacent arteries and potentially disrupt traffic flows on those facilities.
- <u>Severe congestion</u> - The freeway should operate a level-of-service E or worse during peak hours, otherwise delays at the controls will likely be perceived as exceeding the travel time reduction on the freeway and opposition may develop.
- <u>Surface routes</u> - Ramp controls will tend to divert short trips from the freeway to surface streets, at least partly by design. Other problems, such as delays or through traffic on residential streets, are likely if adequate routes and capacity are not available for these trips.
- <u>Minimal flow control</u> - Traffic already on the freeway cannot be controlled, and some entering traffic may remain uncontrolled due to feasibility or cost problems (e.g., ramps with inadequate storage or low volumes). If less than 30% of the facility's volume is controllable, excessive ramp delays will be necessary if congestion is to be reduced.

<u>Potential Implementation Problems</u>:

- Traffic and congestion levels on nearby surface streets may increase as a result of freeway users changing their access routes to use less congested ramps or of short trips diverting from the freeway. Opposition may be strong if congestion problems are transferred from one jurisdiction to another as a result of the action.

<u>Potential Implementation Problems (Cont'd.)</u>:

- Violation of control signals (or of bypasses reserved for buses and carpools) may be high if a metering rate below about six vehicles per minute results in queues. The problem will likely be worse where freeway congestion is not visible from the ramp.

<u>Potential Evaluation Factors</u>:

- Congestion reduction:
  - changes in peak operating speeds or levels-of-service on freeway sections (speed increases of 3 to 10 mph are likely)
- Travel time:
  - change in ramp-to-ramp travel times for selected routes (.3 to .4 minutes per mile typical along freeway, but may be offset by time spent in ramp queue)
- Air quality:
  - change in air pollutant emissions on freeway section during peak periods
- Freeway operations:
  - installation costs, including ramp modifications
  - annual operating and maintenance costs of control devices
  - changes in enforcement costs
- Surface street flow:
  - changes in traffic volumes on affected surface streets in the freeway corridor
  - changes in operating speeds or levels-of-service on affected surface streets
  - change in traffic volumes on affected surface streets during peak periods
  - changes in operating speeds or levels-of-service on affected surface streets during peak periods

Potential Evaluation Factors (Cont'd.):

- Accident reduction:
  - change in number of accidents or accident rate on freeway sections

References:

(1) Blumentritt, C.W., et al., "Guidelines for Selection of Ramp Control Systems", NCHRP Report 232 (May 1981) 108 pp.

Describes ramp control design and operations options, and presents guidelines and analysis procedures. Little information on specific cases.

(2) Spielberg, F., et al., Evaluation of Freeway High Occupancy Vehicle Lanes and Ramp Metering, Volume 1: "Final Report", Report No. DOT-P-30-80-28 (August 1980) 136 pp.; Volume 2: "Bibliography and Abstracts", Report No. DOT-P-30-80-29 (August 1980) 140 pp.

Volume 1 briefly describes projects in San Jose, Atlanta, Chicago, Detroit, Dallas and Houston, and discusses their effectiveness. Volume 2 contains abstracts of the following project evaluation reports on I-35W in Minneapolis and the North Central Corridor in Dallas:

- USDOT/FHWA, Office of Research Ramp Meter Bypass for Carpools, Report No. FHWA-76-189, Washington DC (Oct. 1976)
- USDOT/UMTA, Office of Transit Planning, Final Report for the I-35W Urban Corridor Demonstration Project, Washington DC (August 1975)
- USDOT/FHWA, Office of Research, Dallas Corridor Study, Report No. FHWA-RD-77-15, Washington DC (August 1976)

References (Cont'd.):

(3) Billheimer, J.W. et. al., TSM Project Violation Rates, prepared by Systan Inc. for State of California, Department of Transportation and Department of the Highway Patrol, USDOT report No. DOT-I-82-10 (October 1981) 280 pp.

Discusses and analyzes enforcement, violation and accident experience at several ramp meter bypasses in Los Angeles and San Diego, and examines a model enforcement program.

14

Profile 14: Freeway Ramp Closure

Some sections of older freeways have close ramp spacing, short weaving and merging distances, and tight curves on the mainline and ramps. These design features can result in high accident rates and instability of traffic flow. While the geometric changes necessary to fully solve the problems are expensive, the selective closure of ramps may provide a low-cost partial solution.

Problems Addressed:

- Shock effects of traffic entering, leaving and changing lanes on a freeway consistently produce traffic congestion during peak travel periods.
- A high number of accidents occur as a result of merging and weaving maneuvers.
- Ramp users contribute to congestion or other problems on nearby streets or centers that are difficult or expensive to solve without rerouting traffic.

Condition for Application:

- Continued access - Ramps that remain open in the vicinity should have sufficient excess capacity to handle the traffic currently using the ramps proposed for closure, as should streets leading to those ramps. In addition, alternative routes should be available for any bus and truck traffic using the ramps to be closed.
- Close ramp spacing - The action will be most effective in improving traffic flow where ramp spacing is 500 feet or less, or where less than 400 feet per lane change is available to accomodate a strong cross flow (e.g., an enter on right, leave on left maneuver).

Potential Implementation Problems:

- Traffic diverted to adjacent ramps or off the freeway may cause an increase in traffic and congestion levels on surface streets. Opposition may be strong if problems are transferred from one jurisdiction to another as a result of the action.

Potential Evaluation Factors:

- Congestion reduction:
  - change in peak operating speed or level-of-service on freeway section
  - change in traffic volumes on affected surface streets during peak periods
  - changes in operating speeds or levels-of-service on affected surface streets during peak periods

Potential Evaluation Factors (Cont'd.):

- Accident reduction:
  - change in number of accidents or accident rate on freeway section
- Costs:
  - cost of barricading or removing ramps

References:

(1) Homburger, W.S. (editor), Transportation nd Traffic Engineering Handbook Second Edition, Institute of Transportation Engineers, Prentice-Hall, Inc., Englewood Cliffs NJ (1982) 880 pp.

Other Example:

- Boston, MA - Two ramps were closed to traffic and dismantled along a 1 mile elevated section of the Central Artery, a limited-access highway constructed through downtown Boston in 1948, to reduce the accident rate on the highway and open pedestrian access to the waterfront to support an extensive redevelopment effort.

Profile 15: Travel on Freeway Shoulders During Peak Periods

Under some circumstances, freeway shoulders may be used as travel lanes during peak periods to increase facility or corridor capacity.

Problems Addressed:

- Traffic congestion consistently develops on a freeway or in a freeway corridor during peak commuting periods.
- Localized traffic congestion develops on a freeway as a result of a lane-drop.

Conditions for Application:

- Adequate geometry - Ten-foot shoulders are required; wider shoulders are preferable where structures or guardrails abut the shoulder. Horizontal and vertical alignment must allow sight distances that are safe for the speed anticipated in the shoulder lane. In addition, merging zones and sight lines between on-ramps and the shoulder lane must not be reduced below levels required for safe operation.
- Regular users - The use of the shoulder as a travel lane reduces the margin for driver error. Consequently, the action is less likely to cause safety problems if implemented during peak commuting hours on facilities where at least 80% of the drivers are regular commuters and thus familar with the facility and specific temporal flow patterns.
- Few trucks - If over roughly 3% of the traffic flow during the peak period consists of heavy trucks, merging and lane-change movements may be difficult in the right-hand and shoulder lanes. This condition may lead to traffic flow disruptions and an increase in accidents.

Potential Implementation Problems:

- The shoulder will no longer be free for breakdowns and traffic enforcement, so operating procedures need to be established with police and other safety officials to maintain safe freeway operations and avoid major traffic jams.
- Some of the capacity added by the shoulder lanes will be used by drivers diverting from arterial streets for short segments of their trips, or by drivers shifting the timing of their trips. Their presence will limit the congestion-reducing impact of the action, and the added merging volumes may increase accidents on the freeway.
- If the shoulder lane is not continuous, or if ramp and egress capacity is limited near major employment centers along the freeway corridor, traffic congestion may simply be shifted from one location to another when the action is implemented.

Potential Evaluation Factors:

- Volume increases (due to changes in timing or routing of trips):
  - changes in hourly traffic volumes on facility during peak periods (10% to 25% increases may occur during the peak hour)
- Congestion reduction:
  - changes in peak operating speeds or levels-of-service on freeway sections (speed increases of 3 to 10 mph are likely, depending on existing congestion levels).
- Traffic diversion:
  - changes in peak traffic volumes on parallel facilities
  - changes in peak operating speeds or levels-of-service on parallel facilities
- Freeway operations:
  - implementation costs, including ramp modifications
  - change in maintenance costs of freeway sections
  - change in enforcement costs
- Safety:
  - change in accident rate on freeway

References:

(1) U.S. Department of Transportation, Federal Highway Administration, "Freeway Modifications to Increase Traffic Flow", Report No. FHWA-TS-80-203 (January 1980) 109 pp.

Describes design and implementation considerations, and provides a 1-page summary of projects including costs and effectiveness. Examples include sections on the Santa Ana Freeway (Los Angeles CA), Southeast Expressway (Boston MA) and I-280 (San Jose CA).

16

Profile 16: One-Way Streets to Improve Flow

Turning and parking movements interfere with through-traffic using the inner and outer lanes of surface streets, reducing their effective capacity. The conversion of sets of streets to one-way operation in a subarea or along a corridor may be a very effective and inexpensive means of adding capacity and reducing congestion delays. The action also may simplify signal timing and coordination, particularly where turning movements and pedestrian volumes are large.

Problems Addressed:

- Traffic congestion consistently develops in a subarea or along a corridor during peak travel periods.
- Accidents involving turning movements occur frequently in a subarea or along a corridor.
- Congestion is expected to increase if business expansion plans are approved and implemented.
- Air pollutant concentrations that develop in subarea or corridor can be attributed to peak traffic flow conditions.

Conditions for Application:

- Narrow streets - In general the action is more effective where street widths preclude more than three travel lanes.
- Balanced capacity - A one-way street system should provide nearly equal capacities (on a daily basis) in the two directions crossing any screenline. This is most simply achieved by pairing parallel streets with the the same number of lanes and comparable operating speeds. More complex plans, however, can operate effectively, and actions such as reversible lanes and on-street parking bans may be included in the project package to alleviate capacity deficiencies during peak traffic periods.
- Dense signal spacing - If intersections requiring signalization are more closely spaced than a quarter mile, a one-way street system will simplify the coordination of signal phases. Separate phases for left turns are not required, and independent progressions can be set for each directional flow.
- Transition areas - The transition from two-way to one-way streets, and vice versa, should be clear and easy to negotiate. Geometric and signalization changes usually are necessary to create this condition, and some land acquisition may be necessary.

Potential Evaluation Factors:

- Capacity increase:
  - change in hourly capacity of street system (20% to 50% increase on converted streets)
- Congestion reduction:
  - change in average peak operating speeds on arterial streets in the corridor or subarea (5% to 20% increased in speed can be achieved)
- Accident reduction:
  - change in number or rate of accidents on arterial streets in the corridor or subarea (between 20% and 60% of accidents involving turning movements can be eliminated)
- Air quality improvement:
  - change in air pollutant emissions in corridor or subarea during peak travel periods
- Street operations:
  - implementation costs, including any land acquisition and geometric or signalization changes in the transition area
  - change in annual maintenance costs of arterial streets in corridor or subarea

References:

(1) Homburger, W.S. (editor), Transportation and Traffic Engineering Handbook, Second Edition, Institute of Transportation Engineers, Prentice-Hall, Inc., Englewood Cliffs NJ (1982) 880 pp.

(2) Edwards and Kelcey, Inc. "Optimizing Flow of Existing Street Networks," NCHRP Report No. 113, Washington DC, (1971) 414 pp.

Presents a "before-after" study of three small one-way systems in Louisville KY and Newark NJ.

Other Examples:

- Saginaw - Oakland Streets, Lansing, MI
- CBD Bypass, Poughkeepsie, NY

Profile 17: One-Way Streets to Impede Flow

Circulating and through-traffic may degrade the quality of a residential neighborhood or a commercial center, and may create a hazard for pedestrians. One-way streets can be used in these situations to block through movements and discourage drivers from entering the neighborhood or center.

Problems Addressed:

- Through traffic on residential streets creates a hazard to residents and degrades the residential quality of the neighborhood.
- Through or circulating traffic in a commercial center conflicts with pedestrian movement or contributes to noise or air pollution.

Conditions for Applications:

- Narrow rights-of-way - The action will work best, particularly in a residential area, on streets with only one or one-and-a-half travel lanes. The one-way restriction will be partially self-enforcing if opposing traffic flows cannot conveniently operate. Widened sidewalks or added on-street parking and loading zones can be implemented to create this condition.
- Alternative routes - Convenient routes with adequate capacity should be available for through traffic diverted from local streets. Parking facilities in a commercial areas also should remain easy to drive to and from, and feasible routes should be available for buses and delivery trucks.

Potential Implementation Problems:

- Complex systems that are confusing to residents or shoppers will be difficult to enforce, and will be opposed by store owners or residents.
- Simple circulation routes should be provided for services such as mail delivery and garbage collection, otherwise the costs of these services will increase.

Potential Evaluation Factors:

- Street availability and use:
    - change in number of straight routes through neighborhood or center
    - change in traffic volumes on neighborhood or center streets
    - change in tour distance of routine delivery and service vehicles

Potential Evaluation Factors (Cont'd.):

- Arterial street congestion:
    - changes in operating speeds or levels-of-service on adjacent arterial streets
- Commercial activity:
    - change in parking space occupancy in center
    - change in parking revenues
    - change in retail sales in center
- Street system operations:
    - implementation costs
    - annual maintenance costs of signs, etc.
    - change in enforcement costs
    - change in fine revenues

References:

(1) Smith, Daniel T. and D. Appleyard, "Improving the Residential Street Environment," Report No. FHWA/RD-81/031 (May 1981) 149 pp.

Other Examples:

- Boston, MA - South End and Charlestown
- Cambridge, MA - residential neighborhoods
- Madison, WI, Capitol Square

18 Profile 18: Reversible Lanes

Traffic flows in many corridors and subareas are unbalanced during peak travel periods, with ratios over 2:1 not uncommon. One approach to reducing congestion and delays during peak periods is to reallocate street and highway capacity to better match traffic volumes. This can be accomplished by reversing the normal operating direction of lanes or designating roadways for one-way operation at appropriate times.

Problems Addressed:

- Traffic congestion consistently develops in a subarea or along a corridor during peak travel hours.
- Air pollutant concentrations in a corridor or subarea can be attributed to congested traffic and idling vehicles.
- Congestion is expected to increase if business expansion plans are approved and implemented.

Conditions for Application:

- Safe operation of opposing flows - Heavy striping and overhead signs or signals usually are sufficient to maintain separation of opposing traffic flows on a surface arterial with operating at speeds up to 40 mph. Movable barriers may be advisable on higher speed roads. On freeways, the best configuration is two or more center lanes separated from other travel lanes by guardrails or medians (e.g., I-5 in Seattle WA), which may require a major reconstruction effort to achieve.
- Sufficient capacity for minor flow - Sufficient capacity should be available in corridor to accomodate the minor directional flows with no signicant increases in travel times. Four-lane or wider corridor arteries generally should not be operated with only one travel lane in the minor direction, but this operation may be acceptable over short distances in a subarea.
- Absence of barriers - Medians, islands, turn lanes and other channelization devices often will interfere with the design and operation of reversible lanes, so streets free of these impediments usually are the best candidates for lane reversal.

Potential Implementation Problems:

- Motorist confusion about the directionality of a lane can lead to accidents. Clear striping, signing and signalization can be designed to avoid this problem. In addition, the lanes should be closed prior to reversing their operation to allow all vehicles to clear.

Potential Evaluation Factors:

- Capacity increase:
  - change in directional hourly capacity during peak travel period (5% to 15% increase in a subarea or corridor)
- Congestion reduction:
  - change in average peak operating speeds or levels-of-service in the corridor or subarea (speed increases of 3 to 10 mph may be achieved)
- Air quality:
  - change in air pollutant emissions during peak period in the corridor or subarea (3% to 5% reductions are likely)
- Street operations:
  - implementation costs
  - operating and maintenance costs of lane control devices
  - change in traffic enforcement costs
- Safety:
  - change in number or rate of accidents in the corridor or subarea

References:

(1) Rowan, N.J., D.L. Woods, and V.G. Stover, Alternatives for Improving Urban Transportation", A Management Overview, Prepared for FHWA by Texas Transportation Institute, Texas A&M University, (October 1977).

Summarizes costs, effectiveness and implementation issues of reversible lanes and other traffic flow improvements.

(2) Pontier, W.E., P.W. Miller and W.H. Kraft, Edwards and Kelcey, Inc., "Optimizing Flow in Existing Street Networks", NCHRP Report 113, Washington DC (1971) 414 pp.

Presents a "before-after" study of reversing lanes on Broad St. in Newark NJ.

References (Cont'd.):

(3) Institute of Transportation Engineers, "Guidelines for Urban Street Design", Washington DC (1979) 150 pp.

Provides general guidelines on reversible lanes and streets and cites some examples, including Michigan Ave. in Dearborn (MI) and Farnam St. in Omaha (NB).

(4) Agent, K.R. and J.D. Clark, Kentucky DOT, "Evaluation of Reversible Lanes (Nicholasville Rd., Lexington, KY)", Lexington KY (July 1980) 70 pp., NTIS # PB81-123085

Describes the implementation of a reversible lane on a 5-lane arterial street and presents before-after travel time, delay and safety data. The project involved special signals that enabled a 2-way left-turn lane to be shifted by one lane during peak periods.

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Profile 19: Two-Way Left-Turn Lanes

Frontage development along suburban arteries typically has off-street parking accessed through curb cuts and side streets. Left turns to and from these access points may conflict with through-traffic, even when the traffic is organized into platoons by signal progression. A two-way left-turn lane in the center of the roadways allows a place for drivers turning left to wait for gaps in the flow they are crossing or entering without disrupting traffic.

Problems Addressed:

- Left turns off of and onto an arterial street at uncontrolled points interfere with traffic flow and contribute to delays.
- Left turn movements away from controlled intersections are a major factor in accidents reported along an arterial street.

Conditions for Application:

- Roadway width - A two-way left turn lane generally can be added to streets with 12-foot or wider lanes by narrowing the lanes to 9 feet or 10 feet. In other cases, parking may have to be removed or the roadway widened to accommodate the added line.
- Diffused turning movements - Left-turn movements should be distributed fairly evenly along the lane. If a few major traffic generators, such as shopping centers, are the source of most turns, fixed turn lanes with coordinated signals probably are a better solution.
- Signal spacing - The lane should be operated as a standard left-turn lane at each signalized intersection, with storage space for at least three vehicles. If signals are spaced closer than a fifth of a mile, less than half of the lane may be available for two-way operation.

Potential Evaluation Factors:

- Congestion reduction:
  - change in peak operating speed along arterial street (up to 5 mph increase depending on turning volumes)
- Accident reduction:
  - change in number or rate of accidents involving left turns along arterial streets
- Street operation:
  - implementation costs, including any intersection modifications
  - annual cost of maintaining lane markings and signs

References:

(1) Homburger, W.S. (editor), Transportation and Traffic Engineering Handbook", Second Edition, Institute of Transportation Engineers, Prentice-Hall, Inc., Englewood Cliffs NJ (1982) 880 pp.

(2) Institute of Transportation Engineers, "Guidelines for Major Urban Street Design", Washington DC (1979) 150 pp.

Provide general guidelines, and cites examples including Washington St. in Augusta (GA) and Sunshine St. in Springfield (MO).

(3) Engineering Experiment Station, Ohio University, "Development of Guidelines for the Application of Continuous Two-Way Left-Turn Median Lanes", NTIS No. PB-247-300 (July 1975) 105 pp.

Profile 20: New Street Segments

Many cities have corridors that lack good cross streets, and cross-corridor travel in suburbs often is limited by the former county road network initially laid out to serve farms and small towns. Street offsets and other network discontinuities force cross-corridor travelers onto radial segments for parts of their trips, often causing safety problems or adding to congestion on those facilities. In some cases, short segments can be added, or intersections can be redesigned, to eliminate small network discontinuities.

Problems Addressed:

- Delays and low average travel speeds on cross-corridor routes.
- Drivers use residential streets to avoid bottlenecks.
- Traffic congestion and delays on a radial street or highway can be attributed to cross-corridor traffic forced onto the facility.
- Accidents at intersections can be attributed to turning movements involving cross-corridor traffic.
- Business expansion plans are expected to produce traffic flows that cannot be handled well by the existing street network.

Conditions for Application:

- Available rights-of-way - The action is most feasible where it can be accomplished within existing rights-of-way or where minimal land acquisition is required. As acquisition costs increase, higher travel time savings will be required to justify the investment.

Potential Evaluation Factors:

- Route shift (the means of accomplishing other objectives):
  - changes in peak traffic volumes on street sections in study area
- Delay reduction:
  - change in peak travel times along cross-corridor or other impeded routes
  - change in level-of-service of intersections affected by the action
- Safety:
  - changes in turning conflicts at intersections
  - changes in accidents or accident rates at intersections

Potential Evaluation Factors (Cont'd.):

- Street operation:
  - construction cost of new segment and associated improvements
  - annual maintenance cost of new segments and associated improvements

References:

(1) Homburger, W.S. (editor), Transportation and Traffic Engineering Handbook, Second Edition, Institute of Transportation Engineering, Prentice-Hall, Inc., Englewood Cliffs NJ (1982) 880 pp.

21

Profile 21: Signal Phases for Left Turns

Traffic turning left at an intersection can disrupt traffic flow and cause delays and accidents. Adding a left-turn phase to a traffic signal will separate left turn and opposing through-flows. Advancing the green phase in one direction to allow turns to be made ahead of the opposing flow also will accomplish this separation where turning movements are predominantly in one direction.

Problems Addressed:

- Traffic turning left is commonly delayed more than one signal cycle during peak travel periods.
- Accidents at an intersection can be attributed to conflicts between vehicles turning left and opposing traffic or pedestrian flows.
- Vehicles turning left disrupt the opposing traffic flow and cause delays.

Conditions for Application:

- Constraints on free turn - Turns through the opposing traffic flow on an open green phase should be contrained by the volume of opposing traffic, the frequency of pedestrian crossings, the number of lanes to be crossed, and the speed of opposing traffic. In general, left turns across three lanes (two lanes if speeds are over 40 mph) of opposing traffic should be protected. Jug-handles and other rerouting of turning traffic are alternative actions.
- Flow separation - Adequate turn lanes should be available to store turning vehicles so they do not interfere with through traffic. If the turn phase precedes the straight-ahead phase, turning vehicles should not be blocked from the intersection by waiting vehicles.

Potential Implementation Problems:

- During periods when gaps in the opposing traffic are common, drivers turning left will be unnecessarily delayed by a separate turn phase. Permitting turns during the straight green phase (see references 3 and 4) will avoid these delays, but may create a safety problem.
- Left-turn phases introduced by increasing cycle time may interfere with signal coordination.
- A left-turn phase will reduce capacity available to other flows and may increase delay.

Potential Evaluation Factors:

- Delay change:
  - change in level-of-service of affected intersections in peak and off-peak periods
  - change in delays at intersections in peak and off-peak periods (left turns through traffic; and total)
- Accident reduction:
  - change in number of accidents at intersection (up to 30% reduction likely)
- Street operation:
  - implementation costs, including any geometric changes
  - change in annual maintenance costs of intersection

References:

(1) Wagner-McGee Associates, "Traffic Control System Improvements: Impacts and Costs," report prepared for USDOT/FHWA (March 1980).

(2) Agent, K.R. and R.C. Deen, Kentucky DOT, "Warrants for Left-Turn Signal Phasing", Transportation Research Record 737, Washington DC (1979) pp. 1-10.

Reviews guidelines used in 45 states, analyzes volume, delay and safety criteria, and recommends a set of warrants. Analysis includes before-after delay and conflict data for three intersections.

(3) Perfater, M.A., Virginia Highway and Transportation Research Council "An Assessment of Exclusive/Permissive Left Turn Signal Phasing", report No. FHWA/VA-82/49, Charlottesville VA (March 1982) 35 pp., NTIS # PB82-231200.

Presents a study of traffic conflicts, accidents and motorists' perceptions at 10 intersections in Virginia where left-turns are allowed during an open green phase even though a separate turn phase is provided.

(4) Mohle, R.H. and T.K. Rorabaugh, A Study of Clearance Intervals, Flashing Operation and Left-Turn Phasing at Traffic Signals, Volume 4, USDOT report No. FHWA-RD-78-49, Fullerton CA (May 1980) 100 pp., NTIS # PB81-105611

Discusses operational issues and options and presents delay, conflict, accident and other results from a study of seven intersections in southern California cities.

22

Profile 22: Reroute Turning Traffic

Traffic turning left at major intersections may conflict with oncoming traffic and with pedestrians; traffic turning right also may conflict with pedestrians and with buses moving in the curb lane. If turn lanes with separate signal phases are infeasible or inappropriate, turn prohibitions can be used to shift one or more of the turning traffic flows to other locations. The prohibition can be in effect at all times or limited to hours of high traffic or pedestrian volumes.

Problems Addressed:

- Traffic delays at an intersection are caused by conflicts between turning movements and pedestrian, bus and/or other traffic flows.
- Accidents at an intersection can be attributed to conflicts between turning traffic and pedestrian, bus and/or other traffic flows.

Conditions for Application:

- Alternative routes - Convenient alternative routes should be available for the traffic flows prevented from turning at specified intersections. The congestion and accident problems should not simply be transferred to another location, and other problems, such as routing additional traffic over residential streets, should be avoided.
- Capacity constraints - Rerouting turning movements probably will add to their travel times and distances. To be justifiable as a congestion-reducing action, the aggregate travel time savings due to improved traffic flow should exceed the aggregate increases experienced by turning traffic. Unless separate turn phases will cause serious additional delays to through traffic, this condition will not be met. As a general rule, both streets should be operating at level-of-service D or worse during the hours of turn prohibition.

Design and Operational Issues

- Alternative routes should be made clear (e.g., by signs showing an around-the-block route for a left-turn), otherwise violations will occur or confused drivers will interfere with traffic flow.
- Cooperation of the police department may be necessary to enforce any turn prohibitions. Initial enforcement followed by random checks should be sufficient.

Potential Evaluation Factors:

- Route shift (the means of accomplishing other objectives):
  - changes in (peak) traffic volumes using street segments and intersections in study area

Potential Evaluation Factors (Cont'd.):

- Delay reduction:
  - change in level-of-service or average delay at affected intersections (up to 30% reduction in delays depending on turning volumes)
  - changes in travel times along straight routes through study area
  - changes in travel times along routes involving turn in the study area
- Accident reduction:
  - change in number or rate of accidents in study area
- Street operations:
  - signing, striping and other implementation costs
  - change in enforcement costs

References:

(1) Homburger, W.S. (editor), Transportation and Traffic Engineering Handbook, Second Edition, Institute of Transportation Engineers, Prentice-Hall, Inc., Englewood Cliffs NJ (1982) 880 pp.

Profile 23: Use of Fleet Vehicles for Carpooling

Many employers own or lease fleets of autos that are used by sales, service, courier, or other personnel during working hours. Some of these vehicles may be available for use in commuting to and from work either by their normal daytime users or by other employees. This action may be a good alternative to a vanpool program where employees' residences are not densely clustered.

Problems Addressed:

- Peak period congestion on roads in, near, or approaching an employment center are expected to increase if business expansion plans are approved and implemented.
- Changes in worksite or reductions in transit service are expected to increase commuting costs of employees.

Conditions for Application

- Vehicle availability - Fleet vehicles often may be in use for company business at the end of the working day, or otherwise unavailable for convenient use by carpools. Since carpools will require a vehicle every day, only a portion of the fleet based at the worksite may be used to implement this action, potentially limiting its applicability to firms to substantial fleets.
- Pooling market - Pool formation rate will be higher where large number of employers have the same work schedule and live in areas at least 5 miles or 20 minutes from the center.

Potential Implementation Problems:

- Mid-level managers and other personnel currently using the vehicles in off hours will resist their loss of prerequisites.
- Insurance and fleet maintenance costs may increase if the action is implemented.
- The action potentially can draw riders from transit, with a reduction in revenues, so employees with good transit service available for their commutes should be given a low priority when fleet vehicles are assigned.

Potential Evaluation Factors:

- Mode shift (the means of accomplishing other objectives):
  - change in vehicle volumes entering (AM) or leaving (PM) center during peak commuting periods

Potential Evaluation Factors (Cont'd.):

- Administration:
  - implementation costs
  - annual costs of operating and administering the action

Examples:

- San Diego (CA) Gas and Electric - following a 6-month pilot project, the program was implemented throughout the company. About 150 carpools now use fleet vehicles on a regular basis. (Contact: Tom Kaiser at (619) 232-4252)

24

Profile 24: Employer-Based Carpool Matching Programs

Increased ridesharing can be an effective means of addressing peak period congestion and related problems, but the coordination required among carpool and vanpool users makes the use of this option difficult for many commuters. Sharing rides with fellow workers may eliminate schedule coordination problems and reduce others, such as initial discomfort with traveling in a small group of strangers. Employers can generate prospective match lists for interested employees to use in joining or forming pools, and regularly disseminate cost savings and other promotional information. In addition to this basic program, an employer can readily offer other incentives, such as the assignment of premium parking spaces to carpools and vanpools.

Problems Addressed:

- Traffic congestion consistently develops during peak commuting periods in, near, or along major approaches to an employment center.
- Congestion is expected to increase if business expansion plans are approved and implemented.
- Change in worksite or reduction in transit service is expected to increase commuting costs of employees.
- Air pollutant concentrations develop during peak commuting periods in, near, or along major approaches to an employment center.

Conditions for Application:

- Long commutes - Commuters traveling less than 5 miles and 20 minutes are unlikely to shift from driving alone, for the time spent picking up riders in the morning and dropping them off in the afternoon would significantly increase their commuting time. The action will be more effective where many employees have long commutes.
- Large firms - A firm or government agency with 500 or more employees and regular working hours generally provides the best site for this action, for prospective match lists will be sufficiently lengthy to accommodate many considerations that are important to individuals in selecting fellow riders. Associations of companies in industrial parks and other employment concentrations also can be formed to increase the probability of individuals finding good matches.
- Management commitment - Changes of residence or workplace are common in most urban areas, so ridesharing will decline at a site unless management supports an active, ongoing program to find new members for existing pools and encourages the formation of new pools. Strong commitment is more likely if clear benefits, such as reduced parking space requirements, increased attendance rates or easier employee recruitment are anticipated.

Conditions for Application (Cont'd.):

- Limited transit service - If many employees in the center have the option of using transit, the action may divert more transit riders than auto drivers to carpools, minimizing the impact on congestion while decreasing transit revenue.

Potential Evaluation Factors:

- Mode shifts of users (the means of accomplishing other objectives):
  - changes in hourly vehicle volumes entering (AM) or leaving (PM) center during peak commuting hours
  - changes in hourly vehicle volumes on key approach segments during peak commuting hours
- Congestion reduction:
  - changes in peak operating speeds on key segments in, near, or on approaches to center during peak commuting hours
- Air quality:
  - change in air pollutant emissions during peak periods on key segments in, near, or along approaches to center
- Transit operations:
  - changes in peak ridership and revenue on routes serving center
- Parking operations:
  - changes in parking lot and garage patronage, revenues and operating costs
- Administration:
  - costs of implementing and operating the action

References:

(1) Multisystems and Skidmore, Owings and Merrill, "Ridesharing Implementation Guide," developed for USDOT/FHWA under Contract DTFH61-80-C-00182 (1981) 150 pp.

A detailed guide for setting up and running a corporate ridesharing program. A program at AETNA Life and Casualty (Hartford CT) is presented as a case study.

(2) USDOT, "How Ridesharing Can Help Your Company, a Manual for Employers" (May 1980) 47 pp.

Discusses key issues in setting up a program, and provides cost data on several employer programs.

(3) Misch, M.R., et. al., "Guidelines for using Vanpools and Carpools as a TSM Technique", NCHRP Report No. 241, Washington DC (December 1981) 155 pp.

Discusses applicability, planning, design and implementation issues, and packaging with complementary TSM actions.

25 Profile 25: Employer Vanpool Programs

Increased ridesharing can be an effective means of addressing peak period congestion and related problems, but the coordination required among carpool and vanpool users makes the use of this option difficult for many commuters. Sharing rides with fellow workers may eliminate schedule coordination problems and reduce other problems, such as initial discomfort with traveling in a small group of strangers. Employers can generate prospective match lists for interested employees to use in joining or forming pools, and regularly disseminate cost savings and other promotional information. In addition to this basic program, an employer can readily offer other incentives, such as the assignment of premium parking spaces to carpools and vanpools.

Problems Addressed:

- Traffic congestion consistently develops during peak commuting periods in, near, or along major approaches to an employment center.
- Congestion is expected to increase if business expansion plans are approved and implemented.
- Change in worksite or reduction in transit service is expected to increase commuting costs of employees.
- Air pollutant concentrations develop during peak commuting periods in, near, or along major approaches to an employment center.

Conditions for Application:

- Long commutes - Commuters traveling less than 5 miles and 20 minutes are unlikely to shift from driving alone, for the time spent picking up riders in the morning and dropping them off in the afternoon would significantly increase their commuting time. The action will be more effective where many employees have long commutes.
- Large firms - A firm or government agency with 500 or more employees and regular working hours generally provides the best site for this action, for prospective match lists will be sufficiently lengthy to accommodate many considerations that are important to individuals in selecting fellow riders. Associations of companies in industrial parks and other employment concentrations also can be formed to increase the probability of individuals finding good matches.
- Management commitment - Changes of residence or workplace are common in most urban areas, so ridesharing will decline at a site unless management supports an active, ongoing program to find new members for existing pools and encourages the formation of new pools. Strong commitment is more likely if clear benefits, such as reduced parking space requirements, increased attendance rates or easier employee recruitment are anticipated.

Conditions for Application (Cont'd.):

- Limited transit service - If many employees in the center have the option of using transit, the action may divert more transit riders than auto drivers to carpools, minimizing the impact on congestion while decreasing transit revenue.

Potential Evaluation Factors:

- Mode shifts of users (the means of accomplishing other objectives):
  - changes in hourly vehicle volumes entering (AM) or leaving (PM) center during peak commuting hours
  - changes in hourly vehicle volumes on key approach segments during peak commuting hours
- Congestion reduction:
  - changes in peak operating speeds on key segments in, near, or on approaches to center during peak commuting hours
- Air quality:
  - change in air pollutant emissions during peak periods on key segments in, near, or along approaches to center
- Transit operations:
  - changes in peak ridership and revenue on routes serving center
- Parking operations:
  - changes in parking lot and garage patronage, revenues and operating costs
- Administration:
  - costs of implementing and operating the action

References (Cont'd.):

(5) Barton-Aschman Assoc., Inc., Traveler Response to Transportation System Changes, Second Edition, prepared for USDOT/FHWA, Office of Highway Planning, Contract No. DOT-FH-11-9579 (July 1981) 400 pp.

Summarizes volumes and user characteristics of several programs, including 3M (St. Paul MN), TVA (Knoxville TN), Prudential (Newark NJ) and Winnebago (Forest City IA).

(6) Jacobson, S.O., University of Washington, Employer Vanpool Programs: Factors in Their Success or Failure, prepared for USDOT/UMTA, Report No. UMTA-WA-11-0005-78-3 (June 1977) 85 pp. NTIS # PB-276955

Presents results and analysis of a survey of 58 employers with vanpool programs.

26

Profile 26: Freeway Lanes Reserved for Buses or Carpools

More than three-quarters of the peak traffic on many urban freeways consists of autos carrying only a driver. The effective person-carrying capacity of those facilities potentially can be increased by encouraging the use of transit and the formation of carpools and vanpools. The reservation of lanes during peak periods for buses and other high-occupancy vehicles is a means of providing such encouragement, but one that requires careful planning and design.

Problems Addressed:

- During peak commuting periods, traffic congestion is prevalent on a freeway, its corridor, or near the workplaces of commuters using the freeway.
- Air pollutant concentrations along the freeway's corridor or near the workplaces of commuters using the corridor can be attributed to traffic volumes and flow conditions.

Conditions for Application:

- Significant time savings - The action works by encouraging changes in travel mode through travel time savings. In general, lane users (i.e., transit riders and/or carpoolers) must be offered at least 5 minutes advantage over other travellers to overcome the inconvenience of waiting for a bus or assembling a carpool. This condition requires a highly congested interchange or toll plaza, a 5-mile segment with operating speeds under 30 m.p.h., or some equivalent combination of distance and reduced speed.
- Ridesharing potential - If the lane is to be open to carpools and vanpools, it will be more effective in encouraging pools if other conditions exist in the corridor that make ridesharing convenient and attractive. These conditions include long commutes, large employment concentrations, large firms and high parking costs.
- Good express bus service - The action will be more effective if major employment centers in the corridor are served by frequent express buses.
- High vehicle occupancy - The reserved lane(s) should carry at least their share of travellers on the freeway, otherwise the lane reservation will be hard to justify. This condition requires at least 40 buses per hour for a bus-only lane, or at least 10% of autos to carry 3 or more occupants for a 3+ carpool lane on a freeway with few buses.
- Minimal weaving across lane - The freeway section ideally should have no left-lane exits or entrances unless they are restricted to buses and carpools, although a few low volume exceptions may be acceptable on a bus-only lane.

Conditions for Application (Cont'd.):

- Flow separation - For safety, opposing flows ideally should remain separated by a median, although contra-flow lanes reserved for buses only may be separated by movable barriers. Safety problems also may develop when vehicles enter or leave unseparated with-flow lanes if speed differentials are sufficiently high to meet the time savings conditions.
- Ease of enforcement - Reserved lanes will be used by unauthorized vehicles, even when a lane is patrolled. The lanes should have an adjacent shoulder or frequent turnouts where patrol cars can be stationed and where lane violators can be apprehended without interfering with the operation of any lane.

Potential Implementation Problems:

- Strong opposition will develop if travellers not eligible to use the lanes experience or perceive increased congestion levels.
- Unless the lanes are strongly enforced, ineligible drivers will enter the reserved lanes in large numbers, eliminating most of the travel time savings of legitimate users.
- For safety, a contra-flow bus lane needs to be separated by rubber posts or similar devices. The daily setting and removal of these temporary barriers may be expensive, or may interfere with the operation of adjacent lanes.

Potential Evaluation Factors:

- Travel time:
  - changes in travel time of lane users and non-users during hours of lane reservation.
- Mode or route shifts of users:
  - changes in hourly vehicle and passenger volumes (by occupancy category: ineligible autos and trucks, eligible autos and trucks, buses) on facility during hours of lane reservation (generally the peak and shoulder periods)
  - changes in hourly vehicle volumes on parallel facilities and/or on key streets in employment centers served by facility during hours on lane reservation.

Potential Evaluation Factors (cont'd.):

- Air quality:
  - changes in air pollutant emissions during peak periods along key portions of corridor and/or in employment centers served by corridor.
- Facility operations/finance:
  - lane construction or implementation costs
  - change in facility operating and maintenance costs
  - change in enforcement costs
- Transit operation:
  - changes in operating costs on corridor routes
  - changes in ridership and revenues on corridor routes.

References:

(1) Spielberg, F., et. al., Evaluation of Freeway High Occupancy Vehicle Lanes and Ramp Metering, USDOT/OST (P-33)

- Vol. 1 (Final Report) - Report No. DOT-P-30-80-28 (August 1980) 136 pp.
- Vol. 2 (Bibliography and Abstracts) - Report No. DOT-P-30-80-29 (August 1980) 139 pp.

Summarizes and compares performance data collected for the 12 bus or HOV lanes operated on freeways or toll facilities including Shirley Highway (Arlington VA), Banfield Freeway (Portland OR), Route 101 (Marin County CA) and Moanaloa Freeway (Honolulu HI). Report also presents and reviews performance measures and analysis techniques.

(2) Pratt, R.H. and J.N. Copple, Traveler Response to Transportation System Changes, USDOT/FHWA (HHP-22), Contract No. DOT-FH-11-9579 (July 1981) 398 pp.

Summarizes travel time and mode choice changes observed for 15 freeway bus or HOV lanes.

References (Cont'd.):

(3) Simkowitz, Howard J., A Comparative Analysis of Results from Three Recent Non-Separated Concurrent-Flow High Occupancy Freeway Lane Projects: Boston, Santa Monica and Miami, Report No. UMTA-MA-06-0049-78-2, Transportation Systems Center, Cambridge, MA (June 1978) pp.

Summarizes and compares performance and impact data collected for 3 HOV lanes: Southeast Expressway (Boston MA), Santa Monica Freeway (Los Angeles CA) and I-95 (Miami FL), and discusses problems encountered on operating those lanes

(4) Miller, N. Craig and Robert B. Deuser, Enforcement Requirements for High-Occupancy Vehicle Lanes, USDOT/FHWA (HRS-33), Report No. FHWA-RD-79-15 (December 1978) 238 pp.

Presents operating experience from six freeway bus or HOV lanes.

(5) Public Technology, Inc., A Manual on Planning and Implementing Priority Techniques for High Occupancy Vehicles: Technical Guide, Contract No. DOT-OS-60076. (June 1977) 330 pp.

Discussion of planning and design issues, with the Santa Monica Freeway lanes used as case study.

(6) Levinson, H.S., et al., "Bus Use of Highways; Planning and Design Guidelines", NCHRP Report 155 (1975) 161 pp.

Provides guidelines for bus lane design and operation.

(7) Billheimer, J.W. et. al. TSM Project Violation Rates, prepared by Systan Inc. for State of California, Department of Transportation and Department of the Highway Patrol, USDOT report No. DOT-I-82-10 (October 1981) 280 pp.

Discusses and analyzes enforcement, violation and accident experience on 4 HOV lanes in Los Angeles and San Francisco.

27

Profile 27: Priority Freeway Access/Egress for Buses or Carpools

Giving buses and carpools priority access to or egress from freeways can encourage the use of those modes and thus increase a facility's person-carrying capacity. Priority can be provided through bypasses of ramp metering devices (see Profile 13), by restricting selected ramps at major employment centers to use by buses and/or carpools, or by designating bypass lanes at congested ramps.

Problems Addressed:

- During peak commuting periods, traffic congestion is prevalent on a freeway, its corridor, or near the workplaces of commuters using the freeway.
- Air pollutant concentrations along the freeway's corridor or near the workplaces of commuters using the corridor can be attributed to traffic volumes and flow conditions.
- High transit operating costs can be attributed to traffic congestion and delays near major ramps or interchanges.

Conditions for Application:

- High vehicle occupancy - A meter or ramp bypass should carry at least 400 passengers in buses and carpools during the peak hour, and a reserved ramp should carry at least 800 passengers. Lower volumes probably are not worth the implementation and enforcement costs.
- Significant time savings - Time savings should be sufficient to affect transit operating costs and/or mode choice. A 2-minute savings may be enough to reduce operating costs, while 3 to 5 minutes are probably required to measurably influence mode choice.
- Ramp geometry - A meter or ramp bypass lane must extend beyond the normal traffic queue to tap all potential time savings. A bypass lane should be at least 10 feet wide to allow unobstructed passage of buses.
- Ease of enforcement - The occupancy of vehicles using a reserved ramp or bypass should be clearly visible from a stationary patrol car positioned to apprehend violators.
- Adequate alternate routes - If an existing ramp is to be reserved for buses or carpools, routes with slack capacity should be available for autos and trucks diverted from the ramp. If nearby ramps are already congested, their queues will lengthen and potentially disrupt traffic flow on the freeways or adjacent arteries.

Potential Implementation Problems:

- Unless the ramps or bypasses are strongly enforced, ineligible drivers will use the facility, potentially delaying eligible users and creating safety problems.
- Opposition may develop if ineligible users experience increased travel times and delays.

Potential Evaluation Factors:

- Travel time changes:
  - changes in peak period travel time on major travel paths and modes affected by the reservation of the ramps or bypasses.
- Mode or route shifts of users:
  - changes in hourly vehicle and passenger volumes (by occupancy category: ineligible autos and trucks, eligible autos and trucks, buses) on the facility (and on other affected freeway, street and ramp segments) during the hours of ramp or bypass reservation.
- Transit operations/finance:
  - changes in operating costs on routes using the ramps or bypasses (or otherwise affected by their operation)
  - changes in ridership and revenues on routes using the ramps or bypasses (or otherwise affected by their operation)
- Air quality:
  - changes in air pollutant emissions during peak periods
- Facility operations/finance:
  - construction and installation costs
  - change in facility operating and maintenance costs
  - change in enforcement costs

References:

(1) Spielberg, F., et al., Evaluation of Freeway High Occupancy Vehicle Lanes and Ramp Metering, USDOT/OST (P-33)

- Vol. 1 (Final Report) - Report No. DOT-P-30-80-28 (August 1980) 136 pp.
- Vol. 2 (Bibliography and Abstracts) - Report No. DOT-P-30-80-29 (August 1980) 139 pp.

Contains information on a bus/carpool ramp bypass on I-93 (Boston MA), a toll booth bypass on the Bay Bridge (San Francisco/Oakland CA), and six corridors with bypasses at metered ramps.

(2) Blumentritt, C.W., et al., "Guidelines for Selection of Ramp Control Systems", NCHRP Report 232, (May 1981) 108 pp.

Discusses ramp configuration and control devices, and presents analysis and evaluation procedures.

(3) Miller, N. Craig and Robert B. Deuser, Enforcement Requirements for High-Occupancy Vehicle Lanes, USDOT/FHWA (HRS-33), Report No. FHWA-RD-79-15 (December 1978) 238 pp.

Presents operating experience from the San Francisco/Oakland Bay Bridge and ramp meter bypasses on the North Central Expressway (Dallas TX), Interstate I35W (Minneapolis MN) and three freeways in Los Angeles CA.

(4) Rothenberg, M.J. and D.R. Sandahl, JHK and Assoc., Priority Treatment of High Occupancy Vehicle, report No. FHWA/RD-80/062 (January 1981) 125 pp. NTIS # PB81-216582

Summarizes the travel time and volume impacts of HOV ramps in Minneapolis, Seattle, and Los Angeles

References (Cont'd.):

(5) Billheimer, J.W. et. al., TSM Project Violation Rates, prepared by Systan Inc. for state of California, Department of Transportation and Department of the Highway Patrol, USDOT report No. DOT-I-82-10 (October 1981) 280 pp.

Discusses and analyzes enforcement, violation and accident experience at several ramp meter bypasses in Los Angeles and San Diego, and examines a model enforcement program.

28

Profile 28: Arterial Street Lanes Reserved for Express Buses or Carpools

Arterial streets are major traffic conduits in many urban corridors, even those with freeways. The effective person-carrying capacity of those facilities sometimes can be increased by reserving lanes for buses and/or carpools, and the time savings thus provided to users of those modes will encourage their use for commuting trips. The most common design options are: (1) a curb lane reserved for buses, and (2) a median lane reserved for carpools and express buses.

Problems Addressed:

- During peak commuting periods, traffic congestion is prevalent on an arterial street or near the workplaces of commuters using the artery.
- High transit operating costs can be attributed to traffic congestion and delays along the artery.
- Air pollution concentrations along the arterial corridor or near the workplaces of commuters using corridor can be attributed to traffic congestion.

Conditions for Application:

- Adequate street width - At least two unreserved lanes should remain in operation in each travel direction. A one-way street should be at least 30 feet wide and a two-way street at least 50 feet wide.
- Provision for turning traffic - Traffic turning across the reserved lane may disrupt its operation. Roadway right-of-way and adjacent street network and land uses should allow either turn lanes outside the reserved lane, turn prohibitions (with jughandles or around-the-block routing), or advanced green to be implemented to minimize flow disruption. (See Profiles #21 and #22)
- Traffic delay - The artery should operate at level-of-service D or worse during peak hours if the lane is to be effective in saving time. If intersections are signalized, the lane will offer little advantage unless queues often do not clear during a signal cycle.
- Vehicle occupancy - The lane should carry at least 30 buses during the peak hour if reserved for buses only, or carry more than its share of travelers (e.g., 33% or more of peak directional travelers if one of three lanes is reserved) if the lane is open to carpools and vanpools.
- Ease of enforcement - Lane enforcement will be easier if violators can be apprehended with minimal disruption of traffic flow. Breaks in a median or left-turn bays not used during hours of lane operation can be used for enforcing a median lane, and side streets can be used to enforce a curb lane.

Potential Implementation Problems:

- Strong opposition will develop if general travel lanes become more congested.
- Merchants along the artery may oppose a curb bus lane unless alternative parking exists near their stores.

Potential Evaluation Factors:

- Travel time changes:
    - changes in peak period travel time along the artery for eligible and ineligible vehicles.
- Mode or route shifts:
    - changes in hourly vehicle and passenger volumes along the artery, by mode (ineligible auto or truck, eligible auto or truck, bus) during period of lane operation.
    - changes in hourly vehicle volumes on parallel facilities, and on key streets in employee centers served by the facility, during period of lane operation.
- Transit operations/finance:
    - changes in operating costs on bus routes using the lane
    - changes in ridership and revenues on routes using the lane, or operating parallel to the lane
- Air quality:
    - changes in air pollutant emissions along the corridor, or in centers served by the corridor, during peak periods
- Facility operations/finance:
    - construction and installation costs
    - change in facility operating and maintenance costs
    - change in enforcement costs

References:

(1) Spielberg, F., et al., Evaluation of Freeway High Occupancy Vehicle Lanes and Ramp Metering, USDOT/OST (P-33)

- Vol. 1 (Final Report) - Report No. DOT-P-30-80-28 (August 1980) 136 pp.
- Vol. 2 (Bibliography and Abstracts) - Report No. DOT-P-30-80-29 (August 1980) 139 pp.

Summarizes performance data collected on HOV lanes on the Kalanianaole Highway (Honolulu HI) and the South Dixie Highway (Miami FL).

(2) Miller, N. Craig and Robert B. Deuser, Enforcement Requirements for High-Occupancy Vehicle Lanes, USDOT/FHWA (HRS-33), Report No. FHWA-RD-79-15 (December 1978) 238 pp.

Presents operating experience from the South Dixie Highway HOV lanes (Miami FL) and from bus lanes in the Washington (DC) CBD and on Elm/Commerce Streets (Dallas TX)

(3) Public Technology, Inc., A Manual on Planning and Implementing Priority Techniques for High Occupancy Vehicles: Technical Guide, Contract No. DOT-OS-60076 (June 1977) 330 pp.

Discussion of planning and design issues, with bus lanes in Miami and Los Angeles used as case studies.

(4) Pratt, R.H. and J.N. Copple, Traveler Response to Transportation System Changes, USDOT/FHWA (HHP-22), Report No. FHWA-FH-11-9579 (July 1981) 398 pp.

Summarizes travel time and mode choice changes observed for five contra-flow and nine with-flow bus lanes in the U.S. and Canada. Among those not listed above are Fort Worth Avenue and Harry Hine Blvd. (Dallas TX), Third Street (Louisville KY) and Ottawa River Parkway (Ottawa, Ontario).

References (cont'd.):

(5) Roark, J.J., "Enforcement of Priority Treatment for Buses on Urban Streets", NCTRDP Synthesis of Transit Practice No. 2, Washington DC (May 1982) 30 pp.

Discusses lane configurations, pavement marking, signing and enforcement of bus lanes on arterial streets.

(6) Rothenberg, M.J. and D.R. Samdahl, JHK and Assoc., Priority Treatment of High Occupancy Vehicles, USDOT Report No. FHWA/RD-80/062 (January 1981) 125 pp., NTIS # PB81-216582

Summarizes enforcement experience and travel time and volume impacts of HOV lanes on Arlington Blvd. (Arlington VA), Broadway/Lincoln Sts. (Denver CO) and South Dixie Hwy. (Miami Fl), and of a median bus lane on Barbur Blvd. (Portland OR).

29

Profile 29: Shuttle Buses or Vans

Many suburban and low density urban employment and commercial centers are located away from major transit routes, making travel to these centers difficult for people not having regular access to autos. Shuttle buses or vans operated between a center and nearby rail stations or major bus routes can improve the center's accessibility. Firms in the center can individually or jointly operate the vehicles used for the shuttle, or hire their operation from a charter bus or other agency. Cars and vans currently in employers' fleets can be used for a small-scale employment center operation.

Problems Addressed:

- Travel to an emploment or commercial center is difficult or expensive for people without regular access to autos.
- Increased traffic congestion is expected if business expansion plans are approved and implemented.

Conditions for Application:

- Shuttle distance - The center generally should be within three miles of the transit stop(s) to be served by the shuttle, although longer links can be effective to employment centers on the fringes of an urban area. This proximity will allow frequent service to be provided with a single vehicle and reliable connections with transit schedules to be maintained. Overtime payments to company drivers operating the shuttle also will be minimized by a short travel time.
- Transit service quality - The route(s) connected by the shuttle should offer frequent and reliable service to residences of employees or other (potential) users of the center, otherwise the shuttle will be ineffective in attracting riders. A sheltered waiting area at the transfer point also is desirable.
- Management association - In the absence of a single major employer, retailer or management agency, an association of businesses in the center can provide a mechanism for funding the implementation and operation of a shuttle service.

Potential Implementation Problems:

- Regulatory approval of the shuttle may be required, particularly if its use is not restricted to employees.
- Back-up arrangements will be necessary to insure a high level of reliability.
- Insurance may be expensive or difficult to obtain for private operations.

Potential Evaluation Factors:

- Accessibility:
  - change in number of employees or residents living within a specific travel time by transit
- Shuttle operations:
  - number of trips operated daily
  - daily ridership
  - average daily operating, maintenance, and capital costs
  - daily revenues

References:

(1) Chambers, C., "The Role of the Transportation Broker; Children's Hospital of San Francisco", paper presented at TRB annual meeting, (1983)

Discusses a TSM plan developed to allow a hospital expansion, and briefly describes the implementation of a shuttle van to major transit routes.

Other Examples:

Commercial Union, Quincy MA

Digital Equipment Corp., Maynard MA

Chemical Bank, Jericho NY

Hewlett-Packard, Palo Alto CA

Profile 30: Circulation Buses or Vans

Pedestrian travel within employment, commercial, and special activity centers covering tens or hundreds of acres often is difficult, particularly in centers with large areas dedicated to service roads and parking. The use of private autos for trips within the center may contribute to traffic congestion and air pollution, and be inconvenient if parking occupancy rates are high. Buses or vans operated on loops or shuttle routes can offer a good alternative for many intra-center trips, and can be extended to serve remote parking sites or transit stops (see Profile 29). Firms in the center can jointly operate the routes, or arrange for a private or public operator to provide the service. Existing bus routes also can be modified to provide better circulation service in some centers.

Problems Addressed:

- Pedestrian circulation within a center is difficult or unsafe.
- Business expansion plans will cause traffic congestion unless much of the new parking is added at the fringes of the centers.
- Shoppers and other short-term users have difficulty finding convenient parking in the center.

Conditions for Application:

- Long walking distances - The action will be most effective in centers where major attractions are separated from each other or from large parking facilities by a half-mile or more.
- Parking constraints - Low vacancy rates in convenient short-term parking spaces, high fees for using those spaces, and fees that encourage drivers to leave their cars parked in one spot for at least two hours, all provide incentives for people to use a bus or van for travel within a center. Conversely, if parking spaces are cheap and easy to find, most drivers will use their cars for circulation trips beyond walking distance.
- High vehicle occupancy - The action will be most effective in centers where at least 10% of the people enters as transit or auto passengers.
- All-day circulation - The action works best in mixed-use, retail, medical, educational or transportation centers that have visitors entering and circulating throughout the day. If most of a center's day-time population are employees, a circulation bus will be underused or idle much of the day.
- Large center - In a mixed-use center, a day-time density of at least 20,000 people per square mile may be required to support a circulation transit service. Much smaller densities are required in specialized centers such as airports and universities.

Potential Implementation Problems:

- Traffic congestion in or near the center may interfere with the reliable operation of the circulation service. New road segments or changes in lane operation or signalization may be necessary to avoid congested spots.
- The service may not be noticed by infrequent users of the center. Clearly marked stops with waiting shelters, route maps and schedules will help market the service. Marketing support from businesses and merchants should be obtained.

Potential Evaluation Factors:

- Transit operations/finance
    - implementation costs
    - daily or annual operating costs
    - daily or annual ridership and revenues
- Service quality
    - average wait time
    - average travel time
    - percent of center served
- Street operations/finance:
    - roadway/signal construction and installation costs
    - change in roadway maintenance costs

31

Profile 31: Bus Transfer Stations

Traditional transit networks of radial routes converging on a region's CBD provide poor service for many trips to suburban destinations. The low residential densities and dispersed commercial and employment sites typical of suburban development, however, rarely provide trip densities sufficient to support direct bus service. One option that can provide good service between many pairs of points with a limited number of routes is to establish transfer stations where several routes converge on coordinated schedules to permit transfers without long waits. The stations may have off-street loading areas, sheltered waiting areas, information racks, and other passenger amenities. Parking spaces and drop-off areas for "kiss-riders" also can be provided if regional trunk routes serve the station.

Problems Addressed:

- Travel to jobs and stores is difficult or expensive for people without the regular use of an auto.
- Suburban transit routes required by coverage standards do not attract enough riders to meet cost-recovery and productivity standards.

Conditions for Application:

- Activity centers - While the station is designed to facilitate transfers, the routes serving the station will attract more riders if the station is in walking distance of commercial and business activity. Transferring passengers also will feel safer if they are waiting in a busy location.
- Bus routing - The station should be close to existing trunk routes so they may be routed into the station with little increase in running time or operating cost. Streets used by buses accessing the station should be free of congestion so schedules and connections are maintained without long layovers. In some activity centers, changes in signalization or traffic circulation patterns may be desirable.

Potential Implementation Problems:

- Land for off-street loading in convenient locations may be difficult to acquire or lease; for example, shopping center owners or major tenants may consider transit riders as inferior patrons.
- Existing routes may have to be modified to produce matching cycle times, but these modifications may provide opportunities to improve coverage.

Potential Evaluation Factors:

- Center use:
    - number of passengers boarding and alighting at the transit center during the peak hour, by access or egress mode (i.e., walk, other bus, kiss-ride, park-ride)
    - number of bus routes using the center, and number of bus trips originating, terminating or passing through during peak hour.
- Transit operations/finance:
    - construction cost of the station
    - operating and maintenance cost of the station
    - changes in operating costs on bus routes using the center
    - changes in ridership and revenues on bus routes using the center
- Street operations/finance:
    - construction of roadway and traffic improvements
    - change in roadway operating and maintenance costs

References:

(1) Schneider, J.B., et al., "Planning and Designing a Transit-Center-Based Transit System", Report No. UMTA-WA-11-0007-81-1, (NTIS #PB81-154569) Univ. of Washington, Seattle (September 1980) 133 pp.

Discusses location and design issues, and presents plans and descriptions of 22 case studies, including downtown centers in small cities (Bellingham WN, Brockton MA, Norwalk CT, Davenport IA), suburban centers in larger cities (Beaverton and Cedar Hills in Portland OR), and proposed centers (Denver CO and San Diego CA).

(2) Levinson, H.S., et al., "Bus Use of Highways; Planning and Design Guidelines", NCHRP Report 155 (1975) 161 pp.

Provides design guidelines and standards for off-street bus stations.

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Profile 32: Expanded Regular-Route Bus Service

Many public transit agencies operate under a mandate to provide region-wide service, which often requires expansion into suburban areas. Regular, fixed-route service may be viable in some areas, particularly where multi-family dwellings form corridors from which walk-on passengers can be drawn. Other potential markets for new or extended routes are crosstown operations to employment, shopping, and other activity centers outside the CBD.

Problems Addressed:

- Residential areas with densities that meet warrants for direct bus service are not served by existing routes.
- New or proposed employment or shopping centers are poorly served by existing routes.

Conditions for Application:

- Residential density - Most transit operators have established minimim productivity standards of 20 to 25 passengers per-hour for regular route operations. As a general guideline, residential areas with densities of 4000 people per square mile or more will generate enough trips within a quarter-mile of a route to meet these productivity standards. At densities down to 2000 people per mile, the standards can still be met by drawing passengers from a service area of a half-mile on either side of the route. At lower densities, other types of transit service should be considered.

Potential Implementation Problems:

- Curvilinear and discontinuous streets typical of suburban residential areas may restrict the routing of buses and make coverage standards difficult to achieve.

Potential Evaluation Factors:

- Use
    - changes in ridership on modified routes
- Supply
    - fleet required to operate expanded routes
- Finance
    - capital cost of added fleet
    - change in operating costs on modified routes
    - change in revenues on modified routes

References:

(1) Wagner, F. and K. Gilbert, TSM (Transportation Systems Management): An Assessment of Impacts, report prepared by A.M. Voorhees and Assoc. for USDOT/UMTA (November 1978).

Summarizes ridership changes resulting from system-wide route expansion in eight urban areas: Seattle, Portland, San Diego, Miami, Raleigh, Madison, Eugene and Bakersfield.

(2) Barton-Aschman Assoc., Inc., Traveler Response to Transportation System Changes, Second Edition, prepared for USDOT/FHWA, Office of Highway Planning, Contract No. DOT-FH-11-9579 (July 1981) 400 pp.

Discusses ridership impacts observed in system expansion and route restructuring. Summary results of a few new crosstown and other routes also are presented.

Profile 33: Limited and Skip-Stop Bus Routes

Low passenger loads on the outer portions of radial routes, combined with low reverse direction ridership, reduce bus productivity even in high travel corridors. Variations in loads and running times also may produce schedule adherence problems on long local routes. Several operating strategies may be used to improve bus utilization schedule adherence and travel times in high travel corridors. In addition to express operation on freeways and arterial streets, short turns, segmented routes, "leap-froging" pairs of buses, deadheading buses in the reverse direction, and other means of reducing vehicle-miles or stops made can be used to reduce operating costs or improve service.

Problems Addressed:

- Passenger loads are low on the outer segments of a transit route and in the reverse flow direction (e.g., outbound in the morning peak)
- Long and variable running times lead to schedule maintenance problems and travel delays

Conditions for Application:

- Ridership - Passenger loads should warrant at least 8-10 bus trips per hour during peak periods, i.e., at least 400-500 riders per hour should cross the maximum load point in the peak direction. Otherwise, split operations will produce long wait times or inconvenient schedules for many riders.
- Few destinations - Most riders should be travelling to a few destinations in the morning peak (and from these destinations in the evening peak). Otherwise, stops will be difficult to skip without forcing significant numbers of riders to transfer.
- Corridor length - The corridor should be at least 2 miles long, and a length over 6 miles is preferable.

Design and Operational Issues:

- Buses and stops should be clearly marked, and the operational plan should be easily understood by drivers and riders.
- Separating a route may produce runs of different lengths and running times. These runs may be difficult to coordinate into a coherent schedule without long layover times.
- Riders may oppose increased headways and the need to transfer; free transfers may have to be offered to gain community acceptance.

Potential Evaluation Factors:

- Service quality
  - change wait and travel times (for different trips)
  - change in fare (for different trips)
- Ridership
  - change in patronage (in different markets)
- Transit operations/finance
  - change in vehicle miles operated
  - change in peak vehicle requirements
  - change in operating costs
  - change in revenues

References:

(1) Levinson, H.S., "Bus Route and Schedule Planning Guidelines", NCHRP Synthesis of Highway Practice No. 69, Washington DC (May 1980) 100 pp.

Summarizes planning guidelines used by several U.S. and Canadian cities.

(2) Multisystems, "Bus Route and Service Design - an Overview of Strategies for Major Radial Bus Routes", report prepared for USDOT/UMTA and TSC under Contract No. DOT-TSC-1756 (August 1983) 40 pp.

Overview report describes strategies for bus scheduling in heavily travelled corridors, with examples from Boston, Chicago, and Los Angeles. The screening guide contains screening and design guidelines for different options. Both volumes provide estimates of vehicle and travel time savings.

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Profile 34: Pedestrian-Only Streets

Downtown retail areas in many cities have lost patrons and sales to suburban shopping centers. When implemented in conjunction with a broader urban revitalization program, pedestrian malls may help stimulate such areas by providing an attractive and safe environment for shopping and recreation.

Problems Addressed:

- Vehicular traffic poses safety hazards to pedestrians and impedes pedestrian circulation.
- Vehicle noise and pollutant emissions make CBD streets unattractive to shoppers.

Conditions for Application:

- Adjacent development - Adjacent building should support sufficient pedestrian traffic to make the mall a lively place. Office buildings will provide users primarily at noon and at closing hours. A combination of general merchandise and specialty stores, restaurants, and professional offices will be needed to generate users during other daytime hours, while restaurants and theaters will generate evening users. Libraries, galleries, historical sites and other tourist attractions also will help.
- Access to Transportation - The mall should be convenient to transit stops, taxi stalls and parking facilities, and not require walking through alleys. Shuttle buses from remote parking lots also may be desirable.
- Adequate Street Capacity - Auto traffic will be diverted to adjacent streets, and congestion may increase unless adequate capacity is provided.

Design and Operational Issues:

- Provisions must be made for continued access to parking garages.
- Emergency, service and delivery vehicles must have access to buildings along the mall. During periods of heavy pedestrian use, police supervision of access may be required.
- Merchants and businesses may oppose the mall if it interferes with their operation and inconveniences their customers. Conversely, their support in operating, maintaining and marketing the mall will reduce public expenditures.
- The mall should be easy to clean and maintain, for maintenance costs can be high. (Sparks St. in Ottawa, for example, costs over $250,000 a year to maintain).

Design and Operational Issues (Cont'd.):

- Convenient pick-up and drop-off points should be provided for taxis, autos or vans transporting handicapped people, and auto passengers. These areas may have to be enforced to prevent parking and other abuses.

Potential Evaluation Factors:

- Mall operation/finance
    - construction costs
    - annual maintenance costs
- Streets operations
    - change in level-of-service on adjacent streets
    - change in vehicle and vehicle/pedestrian conflicts in study area
    - cost of traffic improvements
- Transit operations
    - change in operating costs on relocated routes

References:

(1) Transportation Research Board, "Interim Materials on Highway Capacity," Transportation Research Circular No. 212 (January 1980) 272 pp.

(2) Fruin, J.J. Pedestrian Planning and Design, Metropolitan Association of Urban Designers and Environmental Planners, Inc., New york (1971) 206 pp.

(3) Pushkarev B. And Zupan J., Urban Space for Pedestrians, A Report of the Regional Plan Association, MIT Press, Cambridge, MA (1975) ___ pp.

References 1, 2 and 3 provide guidelines for designing pedestrian areas in conformance with anticipated volumes of pedestrian traffic.

References (cont'd.):

(4) A.M. Voorhees and Assoc., "Auto Restricted Zones: Plans for Five Cities", prepared for USDOT/UMTA, report No. UMTA-VA-06-0042-78-3, McLea VA (December 1977) 250 pp.

Presents detailed information on traffic, pedestrian and land use conditions in downtown Boston, Providence, Burlington (VT), Memphis and Tucson, and on the physical and operational plans developed for closing streets for pedestrian malls.

(5) Brombilla, R. and G. Longo, A Handbook for Pedestrial Action, prepared for USHUD by Institute for Environmental Action, Columbia University (1977) 150 pp. available from the US Superintendent of Documents, stock No. 023-000-00373-2. Companion documents by the same authors are The Rediscovery of the Pedestrian - 12 European Cities (Stock No. 023-000-00374-4) 125 pp., and Banning the Car Downtown - Selected American Cities (Stock No. 023-000-00375-9), 150 pp.

The first volume discusses planning and design issues. The others provide cost data and observed changes of congestion, use and retail sales. U.S. case studies include Kalamazoo (MI), Springfield (IL), Sacramento, Burbank and Fresno (CA), Lake Charles (LA) and Trenton (NJ).

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Profile 35: Shared-Ride Taxi

A typical urban area offers only two classes of public transportation: mass transit bus service and exclusive ride taxi. Smaller areas may only have taxi service. Shared-ride taxi offers an intermediate type of service for those who want or need door-to-door service, yet are willing to trade travel time and exclusive occupancy for a lower fare. It also may provide a lower cost sutstitute for transit in low-density areas, during evening hours, or on weekends. Specialized applications, such as region-wide service from an airport, have been implemented in Boston and other cities.

Problems Addressed:

- Community residents without access to automobiles have difficulty traveling to nearby shopping, medical, recreational, and educational and governmental facilities, and to stops on major regional bus or rail lines.
- Regular transit routes in low density areas have high operating costs or low productivity all or part of the day.
- Regular transit routes through a community provide poor service for local trips.
- Roadway and parking facilities at an airport or other major terminal are congested and cannot be expanded to meet anticipated growth

Conditions for Application:

- Potential Matching - Travel requests should be sufficiently frequent to enable a dispatcher to combine riders within 15 minutes about 80% of the time. Lower match rates will not allow a significant discount (of 20% or more) over standard taxi rates. This condition usually requires a population density over 3000 persons per square mile, and is easier if trips are focussed on shopping centers, airports or other major destinations.

Design and Operational Issues:

- Exclusive ride privilege - Patrons should have the right to choose exclusive ride service. If a driver can pick up a street hail against the wishes of someone in the vehicle, the program will not be well received.
- Guaranteed Fares - Many low income patrons must be guaranteed a low (affordable) fare. They may be unwilling or unable to use the service if the low fare is contingent upon the availability of a shared trip.
- Shared-ride pricing - A zone fare system is needed for equity in pricing. Taxi meters do not work well because vehicles do not travel directly between each patron's origin and destination.

Potential Implementation Problems:

- Shared-ride operations are prohibited by ordinance in some jurisdictions.
- Private operators are often willing to extend lower fares only conditionally, i.e., if a ride is actually shared. Guaranteed shared-ride fares are priced to return a profit on average, and drivers and management may balk at losing money on an unshared trip even if it is more than compensated on other trips that are shared.

Potential Evaluation Factors:

- Ridership:
  - no. of shared-ride passengers
  - change in exclusive taxi ridership
- Productivity:
  - passengers per vehicle hour; SRT should be 4-6, as opposed to 2-3 on exclusive taxi
- Taxi Finance:
  - change in operating costs
  - changes in dispatching costs
  - change in revenues and profit margin
- Transit operations/finance
  - change in ridership, revenues, and costs

References:

(1) N.D. Lea & Assoc., Shared-Ride Taxi Implementation and Evaluation Study - (1981) For more information, contact W.G. Atkinson, (604) 922-1211.

Describes the implementation and operation of a shared ride taxi system in the Battlefords, Saskatchewan, as a result of the impending cessation of the fixed route private bus system.

References (cont'd.):

(2) Productivity Improvement For Taxi/Paratransit Industry, proceedings of a conference at Carnegie-Mellon University, (June, 1978) (for more information, contact D.M. Baumann, Department of Mechanical Engineering, Carnegie Mellon University.)

Deals with shared-ride taxi and other productivity innovations. Looks at technology, financial, economic, and regulatory issues.

(3) Davis, Frank W., et. al., Economic Characteristics of Privately-Owned Shared-Ride Taxi Systems, USDOT/TSC Report No. UMTA-06-004-74-3 (1974)

An analysis of privately owned systems in Hicksville NY and Davenport Iowa, including comparison with six publicly owned transit systems.

(4) Teal, Roger F., et. al., Shared Ride Taxi Services As Community Public Transit, Institute of Transportation Studies, U. California-Irvine, (March 1980) Report # CA-11-0017-1

Provides California case studies of shared-ride taxi operations in five different contexts (small city, suburban, large city, transit agency sponsored, E&H) and discusses performance, institutional, contractual, and policy issues.

(5) Billheimer, J.W., et. al., Paratransit Handbook, A Guide To Paratransit Implementation, USDOT/TSC, (Jan. 1979), Report No. UMTA-MA-06-0054-79-2

Contains data on shared-ride taxi operations in 28 small and medium-sized communities.

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Profile 36: Elderly/Handicapped Paratransit Service Brokerage

A city may decide to provide a separate paratransit service for its elderly and handicapped residents, particularly where door-to-door service is necessary. Many human service agencies provide similar services for their clients, and other private carriers may be available to operate service. A central "broker" can be used to organize various operators and users into a single system to achieve economies of scale and effective service quality management.

<u>Problems Addressed</u>:

- Some citizens cannot use public transit, and lack access to an alternative means of low-cost travel.
- Specialized services operated by individual agencies have high operating costs and/or offer low service quality.

<u>Conditions for Application</u>:

- <u>Agency cooperation</u> - Cooperation among human service organizations is essential to successful brokerage. This is easier to develop if funding control is held by a few central offices, and particularly if those offices are all part of city government.
- <u>Significant cost savings</u> - A broker is likely to incur administrative costs approximately 15% to 20% of direct operating costs. This establishes the threshold for lowering operating costs needed to justify brokerage from a strictly economic perspective. Combined service for 5-8 agencies with 15-20 vehicles usually will produce these savings.

<u>Design and Operational Issues</u>:

- Coordination can be designed to aid individual agencies in many different ways. A broker can be used to centralize information and referral for disabled persons, or to centralize purchasing for agencies if they choose to operate their own vehicles.
- A prevalent fear among agencies is that coordination will lead to cross-subsidization of other organizations' clients. In some cases, this prevents coordination; in others (e.g., Norfolk VA), the transit authority voluntarily subsidizes part of the cost of agency trips.

  The broker's central role is both its strength (as a full time transportation manager) and its "weakness" (as an impartial arbiter of service priorities).
- A broker's principal tools in lowering operating costs are improving vehicle productivities and lowering hourly costs.

<u>Potential Implementation Problems</u>:

- A frequent stumbling block is finding one-time funds to pay for startup costs.
- If agencies currently depend heavily on volunteer or unpaid overtime labor, a coordinated system may experience operating costs higher than at present.

<u>References</u>:

(1) Proceedings of the Sixth and Seventh Annual Conferences on Transportation for the Elderly and Handicapped, <u>Transportation for the Elderly and Handicapped - Program and Problems</u>, Volume 1 145 pp., (December 1978.) Volume 2 193 pp., (February 1981) available through the Technology Sharing Office, Transportation Systems Center.

Emphasizes examples of existing special programs that address such issues as insurance, labor, training programs, vehicle selection, user ride subsidy, and brokerage.

(2) Forstall, Keith, et. al., <u>The Port Authority of Allegheny County's ACCESS Program: A Demonstration Retrospective</u>, 1982, For information, contact Keith Forstall, (617) 864-5810.

Discusses the ACCESS brokerage in Pittsburgh PA, and its market penetration, operating costs public, acceptance, and overall performance after three years.

(3) Burkhardt, Jon, et. al., <u>Coordinated Transportation Demonstration Results</u>, OHDS/HEW Report No. HEW-105-76-7404. (February 1980), 140 pp. plus appendices.

Describes the five OHDS coordination demonstrations (Fayetteville, Arkansas; Grand Rapids, Michigan; Howard County, Maryland; Westchester County, NY; and Jacksonville Florida) and assesses why coordination did not work as well in all cases as had been expected.

References (Cont'd.):

(4) Applied Resource Integration, LTD., Guidelines for Coordinated Agency Transportation Service, prepared for OHDS/HEW under Contract No. HEW-105-76-7402 (April 1980)

Two volume "how to" manual of basic design and implementation procedures. Volume 1: Planning Guidelines, 51 pp. Volume 2: Implementation Guidelines, 83 pp.

37 Profile 37: Community Transit Services

The large buses and high operating costs of many regional transit agencies limit the amount of service that can be provided in moderate and low-density areas. Several communities have started their own transit operations using vans or small buses to supplement or replace existing regional routes. Some provide feeder service to bus and rail stations during peak commuting hours, and most concentrate on serving local trips during the midday and evening hours. Common service configurations are pulsing "routes" that converge on a town center and ubiquitous "dial-a-ride." Pulsing services may operate on fixed routes, provide doorstep service, or offer a combination of these options.

Problems Addressed:

- Community residents without access to automobiles have difficulty traveling to nearby shopping, medical, recreational, and educational and governmental facilities, and to stops on major regional bus or rail lines.
- Regular transit routes in low density areas have high operating costs or low productivity all or part of the day.
- Regular transit routes through a community provide poor service for local trips.

Conditions for Application:

- Residential density - Most existing community transit services operate in cities and towns with densities ranging from 1000 to 5000 people per square mile. Operation in higher densities is possible, but fixed-route bus tends to be the most effective operation at those densities and vehicle sizes approach those operated by regional authorities.

Potential Implementation Problems:

- Transit labor unions may oppose the service and attempt to use Section 13(c) of the Urban Mass Transportation Act to force a union contract.
- Approval of the regional transit authority, state public utilities commission, or other regulatory agencies will be required in most states. The laws establishing those agencies, or their policies, may impose restrictions on the service's design and operation.
- If not involved in the operation, local taxi companies may oppose the service as a threat to their financial viability.
- Like most urban transit operations, community transit will require operating subsidies which may produce opposition from local anti-tax groups.

Potential Evaluation Factors:

- Transit operations/finance:
  - implementation costs
  - annual operating costs
  - ridership and revenues
- Service Quality:
  - percent of households served
  - percent of key destinations served
  - average travel time
  - average wait time

References:

(1) Billheimer, J.W., et al., Paratransit Handbook, A Guide to Paratransit Implementation, Report Nos. UMTA-MA-06-0054-79-1 and -2, Systan, Inc., Los Altos, California (January 1979) 828 pp.

Volume 1 discusses the planning, design, implementation and operation of community transit services in detail. Volume 2 contains summary sheets on 58 U.S. and Canadian operations that provide system descriptions, operating policies and performance and cost data. The examples include suburban operations (e.g., La Habra CA dial-a-ride) and small city services (e.g., Ann Arbor MI Teletran).

(2) Peat, Marwick, Mitchell and Co., Analyzing Transit Options for Small Urban Communities, Volume 3, Summary of Management and Operations Experience, Report No. UMTA-IT-06-9020-78-3, Washington, DC (January 1978) 175 pp.

Performance and cost measures from several regular route and demand-responsive systems in small cities are tabulated and plotted for easy comparison.

NOTES

Impact Estimation and Analysis Aids

This section is designed to help an analyst structure an efficient and responsive analysis of both simple and complex transportation management options, and select appropriate estimation techniques for carrying out the analysis. It begins with a discussion of the general types of estimation techniques, the ways in which they can be applied, and factors influencing the choice of appropriate techniques and application procedures. This material supplements the analysis issues presented in Chapter Three of the Procedural Guide (Part I).

The aids that follow this discussion are organized in two sections. The first section presents a set of Method Selection Aids that cover specific types of measures, such as supply/capacity or safety. In addition to specific guidelines on estimation requirements, these aids contain tables that suggest appropriate estimation techniques for different types of analysis and cite manuals, reports, and technical papers that describe and/or illustrate the techniques in detail. The second section contains Notes on Selected Techniques that are not generally available to agencies; these notes are referenced in the appropriate Methods Selection Tables.

- General Types of "Estimation" Techniques

Many techniques are available to estimate performance characteristics of transportation systems and their components and changes in performance resulting from low-cost transportation improvements. These techniques cover a broad range of complexity, and most are applicable to at least some aspects of TSM project planning. While not intended as a rigid classification, the following categories distinguish some of their basic features:

- Specification -- Although not an estimation technique, per se, specification is almost always used to set values of some of the direct transportation and activity measures used in an analysis. (Examples are 15-minute headways on a proposed bus route and level-of-service C on an improved arterial street.)

- Direct measurement or inspection -- Even in an analysis of proposed conditions, values of some measures can be obtained directly from field surveys or maps. Measures such as lane-miles, length of a bus route or garbage collection tour, routes with adequate turning radii for fire trucks or buses, and number of parcels to be acquired for a bypass segment are examples.

- Direct calculation -- Some measures of interest are sums, products, or ratios of other measures. In addition to inter-measures (such as cost per person-minutes saved), financial measures (such as revenues and subsidy requirements) usually are calculated using other estimated values. Summary measures for a study area (such as vehicle-miles of travel) are often the sums of values estimated for components such as intersections and street segments.

- Analogy -- Performance levels and impacts observed for an action at other sites often are the only simple means of estimating many direct and derived measures. Patronage on a proposed community transit service is an example. Data from a single case study or from a compilation or synthesis of several studies may be used, with or without modifications to reflect differences between the characteristics of the sites. The method also is useful in complementing or verifying estimates obtained from analytic methods, because the prediction of impacts outside the range of observed results is a clear indication that errors or oversights have occurred in an analysis.

- Look-up -- Performance and impact levels observed from implementing common actions (or types of actions) sometimes are synthesized into graphs and tables from which estimates can be extracted. The results of research studies employing analytic or simulation models also may be presented in nomographs, graphs, tables, or similar formats from which estimates can be directly extracted. Graphs relating intersection capacity to critical gap and conflicting flows are examples.

- Simple equations and formulas -- Estimates, particularly of derived measures, are often obtained by applying simple equations, unit rates, or formulas. Examples are trend lines or growth rates used to estimate future activity and volume measures, accident and emission rates (per vehicle-mile) applied to estimate safety and air quality factors, and formulas used to allocate transit operating costs among routes based on measures such as vehicle-miles and vehicle-hours. The use of elasticities to estimate changes in volume measures is another example. The coefficients used in the equations often are obtained from look-up tables.

- Analytical or simulation models -- Series of relationships or equations may be required, even in a quick-response environment, to obtain sufficiently accurate estimates of some measures. Some of the analytical procedures may be sufficiently simple or repetitive to apply, so worksheets may be used; while, others, particularly those involving iterative convergence procedures or spatial or temporal interactions, are best applied with the assistance of calculator or computer programs. Examples are mode share and direct demand models used to estimate transit ridership, traffic signal optimization procedures, network assignment models, and analytical procedures used to estimate dial-a-ride vehicle requirements. The table at the top of the following page shows how the different types of techniques are generally used in TSM impact estimation.

TYPICAL APPLICATIONS OF ESTIMATION TECHNIQUES IN TSM PLANNING

	Measure Categories					
Type of Technique	Capacity/ Supply	Service Quality	Volume/ Use	Financial	Public Costs	Activity/ Land Use
Specification	X	X	X			X
Measurement/ Inspection	X	X	X			X
Direct Calc.	X			X		
Analogy	X	X	X	X	X	X
Look-up	X	X				
Formulas	X		X	X	X	X
Models	X	X	X			

- *Different Approaches to Applying Techniques*

Many of the techniques can be applied in different ways depending on available resources and the intended uses of the results. Aside from the obvious choice of manual vs. computerized application, the choices include:

- *Segmentation* -- Varying levels of detail or segmentation can be used in applying many methods. Too much detail will result in unnecessary analysis, while too little will obscure important differences in impacts. Segmentation can be spatial or geographic (e.g., transit route segments or traffic analysis zones), temporal (e.g., peak-hour or period), or based on trip or travel characteristics (e.g., shopping trips or elderly transit riders). In many analyses, only selected segments will be important; examples are peak-hour traffic volumes (by approach and exit) for an analysis of intersection improvements, and CBD-bound work trips in a corridor analysis of express bus options. Although simplification is desirable in TSM planning, detail is necessary in some cases. For example, 15-minute volumes may be better than peak-hour volumes in analyzing improvements to reduce traffic congestion near a large factory, and the use of different income or car ownership levels often is needed for a good estimate of the patronage impacts of a transit fare change.

- *Pivot-point or ratio of change* -- Models have inherent errors that can affect the accuracy of their results, and differences between the local site and the conditions used for their development may limit their direct applicability. A common means of avoiding these problems is to use a model to "estimate" measures under both existing and proposed conditions. The absolute or percentage difference between these estimates is then applied to values observed in existing operations to produce working estimates for analysis or evaluation. Given the small changes expected from most TSM actions, mode choice, traffic assignment, and other analytical models generally should be applied in this manner to avoid detailed calibration to local conditions.

  The estimated percentage change also can be applied to obtain approximate values of measures that are difficult to estimate directly. For example, estimated percentage changes in air pollutant emissions could be used to scale pollutant concentration measurements obtained from metering existing conditions.

- *Borrowed or synthesized information* -- Some information about system operations may be difficult to obtain without an extensive data collection effort. Detailed information on travel, such as origin-destination flows, frequency of trip-making, and socioeconomic characteristics of travellers is a good example. Pieces of information on similar operating conditions and locations often can be assembled to provide some understanding of underlying conditions and provide "default" data for trip distribution and other models. Examples of sources are census data, studies reporting trip length and time distributions, summaries of trip rates for different land uses, and travel surveys.

- *Sensitivity testing* -- Certain post-implementation conditions affecting the performance of proposed actions may be difficult to estimate with any confidence. Proposed land-use changes, for example, may still be in early planning stages with several options under consideration, and an analyst may have doubts about the validity of analogous, borrowed, or synthesized data. Likely ranges of this information, however, usually can be established. An analyst can select two to four values over this range, and estimate values of performance measures under each condition to determine the versatility of proposed solutions. This approach often is easier and cheaper than attempting to develop a better estimate of the uncertain condition. Estimating high and low patronage estimates for a transit service change is an example.

- Reverse application -- Some procedures may be applied backwards from their normal operation to estimate changes necessary to bring about desired impacts (e.g., to meet design criteria). Examples are the reduction in speed-change cycles or increase in carpool/ transit ridership needed to reduce emissions below a threshold, and the capacity increase needed to achieve a desired service quality.

• Factors in Selecting Techniques and Application Procedures

The choice of appropriate methods and application procedures depends on the specific problem, the intended use of the results, and on the information base and other resources. Limited data, planning budgets, time, staff availability, skills and experience, and access to computers all place restrictions on the methods and procedures that can be applied. These restrictions usually are clear, although the best approaches to dealing with them may not be. The accuracy and detail of estimated measures should be keyed to the design and operational decisions they will influence, otherwise the analyst may end up with incompatible or unnecessarily exact estimates.

Several factors influence the required detail and accuracy of estimates; these include:

- Size of likely impact -- Small changes in performance and other measures are difficult to predict with confidence, because they are often smaller than the errors inherent in both the estimation procedure and the observed data. For example, because it is difficult to count traffic more accurately than within ±10 percent, important design decisions should not be based on smaller differences in estimated traffic volumes and associated level-of-service or capacity measures.

- Sensitivity of design features -- Capacity measures and other design features vary in sensitivity to estimated volumes as a result of their integral nature. A rough estimate of patronage, for example, might indicate that two buses were required for a suburban feeder service. If this number would not change with a 40 percent lower or higher patronage estimate, the estimate is quite adequate for determining vehicle requirements.

- Scale of action -- More accurate estimates generally are required for expensive actions or actions with relatively long service lives, because mistakes in changing these actions are likely to be costly or embarrassing to remedy. Small-scale, low-cost actions may need "estimation" only to show they are functional, reasonable, or beneficial.

- Ability to fine-tune -- Many actions easily can be modified after implementation when direct measurements of performance can be made. Examples are signal timing adjustments if queues or delays are observed after signal interconnections are installed, or the addition of bus trips if crowding is observed after routes have been restructured. While most agencies will want to minimize the extent of these modifications to maintain their professional credibility with the public, some reduction in estimation accuracy is appropriate in designing these actions.

The Method Selection Aids that follow expand on these points, and provide guidance in selecting appropriate techniques and application procedures in diverse planning situations.

Method Selection Aids

The aids that follow are designed to assist transportation agencies in (1) setting up simple and efficient analysis plans, and (2) selecting appropriate estimation techniques and application procedures. Aids are provided for seven general categories of performance characteristics or impacts; they contain the following information:

- Specific characteristics or impacts that might be estimated or specified in an analysis.
- Conditions under which estimation is required or desirable.
- Types of procedures that are generally applicable in TSM project planning.
- Appropriate techniques for specific types of common planning and design situations.
- References for further information on the techniques and their application, including cross-references to Action Profiles and Notes on Techniques (e.g., see TN #8).

The aids are intended for use in the action-oriented TSM project planning process presented in Chapter Three of the Procedural Guide, and they are based on the concepts described in that chapter (e.g., the distinction among direct, derived, and intermeasures, and the chaining of their estimation).

A planner should estimate as few performance measures as possible, not as many, and should estimate only at the level of detail required for making design, operational, and implementation decisions. For most low-cost improvements, the impacts or characteristics to be measured and required data items are few, and analytic techniques widely used by traffic engineers and transit operators are appropriate. The tables cite these techniques, as well as methods for estimating measures necessary in more complex corridor and subarea analyses.

Selection aids are provided for the following types of measures and impacts:

1. Supply/Capacity
2. Travel Time and User Cost
3. Safety
4. Travel Volume
5. Finance
6. Air Quality
7. Energy Use

Method Selection Aid 1:
Estimating Supply/Capacity Characteristics

- General

Low-cost TSM actions often involve changes to the physical or operational characteristics of transportation facilities or services. These "supply" changes need to be determined in sufficient detail to allow an early implementation of the action. Examples of transport supply changes are as follows:

- Streets and Highways
    - Physical changes, such as street widening or removal of lanes, a street extension, or an intersection reconstruction to eliminate offsets.
    - Operational changes, such as reversible lanes and streets, a one-way street pair or grid system, signal modifications or coordination, restriping to provide additional travel or turn lanes, conversion of parking lanes for general traffic or bus lanes, or turn controls.
- Parking
    - Physical changes, such as the addition or elimination of spaces.
    - Operational changes, such as time limit changes, neighborhood permits or peak period parking bans.
- Transit
    - Physical changes, such as the addition or expansion of stations, the installation of bus turnarounds, or the addition of bus-only ramps, lanes, or street segments.
    - Operational changes, such as increases or decreases in frequency, extension or modification of routes or route systems, or conversion to express or limited stop service.
- Pedestrian
    - Physical changes, such as a widening of sidewalks, addition of skywalks or refuge islands, or conversion of streets to pedestrian malls.
    - Operational changes, such as the use or elimination of walk-only signal phases or the provision of crosswalks.

Supply/capacity measures take two basic forms. The first is direct or dimensional measures of physical or operational characteristics, such as distances, numbers of travel lanes, parking spaces or buses, hours of operation, transit route headways, or signal phase and cycle lengths. Dimensional changes often are measured or specified directly, but also may be calculated as the amount of facility or service required to carry a design volume at a specified service quality standard (e.g., the number of vans required for a dial-a-ride service carrying 30 passengers per hour with a 20-minute response time). The second form is a capacity measure, typically expressed as the number of persons or vehicles that can be carried per hour by a facility, also at a specified "level-of-service" standard. These measures are usually calculated from the dimensional characteristics or obtained or specified using lookup tables.

- Conditions for Estimation

Analysis of changes in physical and operational characteristics are required for most TSM actions; the major exceptions are (1) regional or policy actions such as parking or transit fare changes, carpool matching programs, or improved transit marketing; and (2) minor changes that do not affect the person or vehicle-carrying capacity or the service quality of a facility. In some cases, an action will produce a variety of supply/capacity changes. For example, a bus lane may increase transit capacity while reducing either parking or general traffic capacity, depending on the prior use of the lane. Similarly, a reversible traffic lane will increase peak-direction capacity while reducing capacity in the opposite direction.

- Estimation Procedures and Methods

Supply/capacity measures for most TSM actions are specified or estimated for individual facilities or services as part of the design or development process. For a specific analysis, measures may be needed for intersections, road segments, transit route segments, transit loading areas, parking areas and/or pedestrian facilities. Measures used in a subarea or corridor analysis usually are either (1) totals within the area, such as the number of short-term parking spaces; or (2) totals across a cutline or screenline, such as the number of arterial lanes or buses entering the subarea or crossing a river. More aggregate measures often are used for a regional analysis such as arterial lane-miles, transit route-miles or bus-miles. Suggested methods for each scale of analysis are presented in the Method Selection Table that follows.

- Supply/Capacity References

1. Sosslau, A.B. et al, COMSIS Corporation, "Quick Response Urban Travel Estimation Techniques and Transferable Parameters: User's Guide." NCHRP Report 187, Washington, D.C. (1978) 229 pp.

2.* Transportation Research Board, "Interim Materials on Highway Capacity." Transportation Research Circular 212 (Jan. 1980) 272 pp.

3. JHK and Associates, Design of Urban Streets, Training Course Manual. Prepared for USDOT, FHWA (HHI-2). (Undated)

4.* Traffic Institute, Northwestern University, "Intersection Capacity Analysis Charts and Procedures." (Undated) (Address orders and inquiries to: Book Dept., Traffic Institute, Northwestern Univ., 405 Church Street, Evanston, IL 60204 (312) 492-5052.)

5.* Leisch, J.E., Capacity Analysis Techniques for Design and Operation of Freeway Facilities. USDOT, Washington, D.C. (1974).

6.* Highway Research Board, "Highway Capacity Manual." Special Report 87, Washington, D.C. (1965) 397 pp.

7.* JHK and Assoc. and the Traffic Institute, Northwestern University, "NCHRP Signalized Intersection Capacity Method." Draft final report for NCHRP Project 3-28(2), Washington, D.C.

8. Homburger, W.S. (editor), Transportation and Traffic Engineering Handbook. Second Edition, Institute of Transportation Engineers, Prentice-Hall, Inc., Englewood Cliffs, N.J. (1982) 880 pp.

9. Fruin, J.J., Pedestrian Planning and Design. Metropolitan Association of Urban Designers and Environmental Planners, Inc., New York (1971) 206 pp.

10. Pushkarev B. and Zupan J., Urban Space for Pedestrians. A Report of the Regional Plan Association, MIT Press, Cambridge, Mass. (1975).

11. Braun, R.R., Reddin M., "Quantifying the Benefits of Separating Pedestrians and Vehicles." NCHRP Report 189, Washington, D.C. (1978) 130 pp.

12. Templer, J.D. et al., Priority Accessible Networks: An Implementation Manual, Provisions for Elderly and Handicapped Pedestrians. USDOT/FHWA (Jan. 1980) 224 pp.

13. Levinson, H.S., Adams, C.L., and Hoey, W.F., "Bus Use of Highways - Planning and Design Guidelines." NCHRP Report 155, Washington, D.C. (1975) 160 pp.

14. Menhard, H.R. and Batchelder, J.H., "A Systems Analysis of Transit/ Paratransit Integration," Volume 6: Guide to Screening Paratransit Service Options. Prepared by Multisystems for USDOT/UMTA, Contract No. DOT-UT-80007 (Nov. 1981) 65 pp.

15. Billheimer, J.W. et al., "Paratransit Handbook, a Guide to Paratransit System Implementation." Volume II, prepared by Systan, Inc., for USDOT/ UMTA, Report No. UMTA-MA-06-0054-79-2, NTIS No. PB81-222135 (Feb. 1979) 378 pp.

16. Batchelder, J.H., et al., "A Systems Analysis of Transit/Paratransit Integration." Volume 5: User's Manual for the MMARS/MMACS Package. Prepared by Multisystems for USDOT/UMTA, Contract DOT-UT-80007 (Sept. 1980) 280 pp.

17. Dial, R.B., Rutherford, G.S., and Quillian, L., Transit Network Analysis: INET. Prepared for USDOT/ UMTA by G.S. Rutherford and Assoc., Report No. UMTA-UPM-20-79-3 (July 1979) 250 pp.

18. Gilbert, K., "Transportation Systems Management: Handbook of Manual Techniques for Transit Strategies." Prepared for North Central Texas Council of Governments (1977), distributed by USDOT/ UMTA, Report No. TX-09-0045-81-1 (1981), 200 pp.

19. Peat, Marwick, Mitchell & Co., "Analyzing Transit Options for Small Urban Communities." Volume 3: Summary of Management and Operating Experience. Prepared for USDOT/UMTA, Report No. IT-06-9020-78-3 (Jan. 1978) 175 pp.

20. Weant, R.A., "Parking Garage Planning and Operation." ENO Foundation for Transportation, Westport, Conn. (1978).

21. Levinson, H.S., "Bus Route and Schedule Planning Guidelines." NCHRP Synthesis of Highway Practice 69, Washington, D.C. (May 1980) 100 pp.

22. USDOT/FHWA, "PLANPAC/BACKPAC General Information." NTIS # PB-240-716, Washington, D.C. (April 1977 and updates) 440 pp.

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* The NCHRP, FHWA, TRB Committee on Highway Capacity and others are conducting research to develop a new Highway Capacity Manual that will replace these references. NCHRP Research Results Digest 140 (February 1983) contains a status report and references to draft material, including references 2 and 7.

1 Method Selection Table 1: Supply/Capacity Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
Spot or Segment Analysis		
● Vehicular capacity of signalized intersections		
- quick determination of adequacy	- apply critical line method (simplified version allows user to calculate capacity without explicitly defining each adjustment factor)	1,2 see TN #10
	- use nomographs or graphic representation of capacity (reduces amount of calculations required)	1-5
	- apply queue length analysis (illustrates capacity in terms of length of waiting queue at each intersection approach; good for situations of closely spaced intersections)	see TN #11
- detailed design and operational decisions	- calculate capacity using a basic lane capacity adjusted for physical characteristics of the roadway, environmental conditions, characteristics of traffic stream, and traffic controls; can be simplified through use of worksheets	6,7,8
	- apply critical lane method (more detailed method allows finer adjustments of atypical characteristics)	1,2
	- apply signal timing methods cited in the Travel Time table to allocate capacity among traffic flows	
● Vehicular capacity of unsignalized intersections (two-way stop or yield sign controlled)	- analyze capacity based upon conflicting volumes and critical gap	2
● Pedestrian capacity of intersections/crosswalks	- estimate space requirements of crosswalks and waiting areas at corners	2
● Road segment or link capacity		
- freeways	- apply updated capacity estimation procedures	2
- urban arterials	- link capacity is controlled by most restricted intersections, so apply intersection techniques for detailed analysis	
	- use nomographs to obtain a rough estimate	1,2
● Walkway capacity	- use dimensional standards (minimum widths and areas, maximum slopes, etc.) to determine requirements	2,9-12
	- use pedestrian LOS analysis to determine adequacy	2,9,10
● Transit vehicle capacity	- use look up tables or manufacturer's specifications to determine bus or rail car capacities	
	- apply estimated rider loads and headway specifications to determine vehicle size requirements	13,16-18
● Transit right-of-way capacity	- use dimensional standards (lane width, turning radius, etc.) for bus lanes, streets or transitways to determine requirements	2,13,21

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* For numbered references, refer to text section of Method Selection Aid #1. Tech. Notes cited may be found in the Notes on Selected Techniques Section.

Method Selection Table 1: Supply/Capacity Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
Spot or Segment Analysis (continued)		
● Transit station capacity	- use dimensional standards (bus bay size, turning radius, etc.) to determine requirements	13,21
	- estimate space requirements (number of bays, curb space, parking, etc.)	13,21
● Parking facility capacity	- use dimensional standards (minimum widths and areas, turning radii, ramp curvature, etc.)	20
Subarea or Corridor Analysis		
● Highway/street system capacity	- treat as a series of individual intersection and segment measurements using techniques above	
	- apply screenline/cutline technique, estimating capacity or travel lanes at each intersection in the cutline	1
● Transit service coverage	- plot routes on base map and estimate percent of population or employment within a 1/4 or 1/2 mile	
	- calculate measures such as vehicle-miles, vehicle-hours or seat-miles by hand or using computer programs	16-19
● Transit capacity (calculation of the number of vehicles needed for operations and other measures used in estimating operating costs):		
- regular bus or rail route	- use running time and headway to calculate vehicle requirements	18 see TN #4
- community (subarea transit and paratransit service)	- apply nomographs to get a rough estimate of bus or van requirements	14
	- use fleet sizes in similar settings to estimate requirements	15,19
	- apply a computerized supply model to calculate fleet size	16
- corridor network of regular bus and/or rail routes	- use computerized network analysis package to estimate or summarize total fleet requirements	16,17
Regional Analysis		
● Highway system capacity		
- macro measurements of capacity changes by facility type and area	- use computerized network analysis package to summarize system capacity	22
	- use number of lane-miles by facility type as a good approximation	
● Transit system coverage		
- sketch planning analysis	- apply manual methods cited for subarea or corridor analysis	

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* For numbered references, refer to text section of Method Selection Aid #1. Tech. Notes cited may be found in the Notes on Selected Techniques Section.

Method Selection Aid 2:
Estimating Travel Time and User Cost Characteristics

- General

The travel times and costs experienced by users of a facility, service, or system often are key factors in assessing performance. TSM actions are frequently implemented to improve these characteristics (i.e., reduce travel time, delays or user costs), or to affect travel decisions (e.g., mode or route choice) by selectively raising or lowering time and cost characteristics.

Several travel time and cost components can be identified, including:

- Streets and Highways
  - Intersection delay or processing time
  - Travel time or speed over a road segment
  - Vehicle operating cost over a road segment
  - Facility or segment toll
- Parking
  - Time spent entering a facility and/or finding a space
  - Time spent walking to and from destination
  - Time spent leaving a facility
  - Parking fee
- Transit
  - Time spent walking to bus
  - Time spent waiting for bus
  - Fare
  - Time spent riding on bus
  - Time spent transferring between buses
  - Time spent walking to destination
- Pedestrian
  - Segment walking time
  - Crosswalk waiting time or delay

In application, these components often are summed, weighted or converted to produce more aggregate measures such as:

- Point-to-point travel times or costs.
- Door-to-door or journey travel times or costs.
- Person-hours, vehicle-hours, or total cost of travel on a facility or service.
- Person-hours, vehicle-hours, or total cost of travel in a subarea or corridor.

Fees, fares, and tolls for using facilities and services are usually specified as part of the proposed plan or design, although journey or average values may be needed for analysis. Calculated averages might be required, for example, if different types of users are charged different fares (e.g., if elderly transit passengers are eligible for discounts). In contrast, travel time and vehicle operating costs generally are calculated or estimated using tables, graphs, or equations. There are exceptions, however; an intersection level-of-service may be specified and used to design lane configurations and a signal system, or a desired arterial travel speed may be used to establish a signal progression.

- Conditions for Estimation

Travel time estimates, or changes in travel time from base conditions, are required under several circumstances; these include:

- Verification that a specified travel time or time savings has been achieved.
- Direct use of travel time or time savings to evaluate the performance of a proposed action.
- "Provider" costs (such as transit operating costs and fleet requirements) are important in the analysis.
- Use of derived measures that vary with speed, delays, and traffic flow conditions for evaluation (examples are air quality improvement and energy use reduction).
- Diversion of travellers to other modes, routes, or time periods is part of the proposed TSM strategy, or likely to occur as a result of implementing the proposed actions.
- Proposed reductions in supply or capacity might result in increases in travel time or delays.

In the first circumstance, a direct estimate of time or time savings may not be necessary. Supply or capacity techniques often can be used to verify a desired level-of-service. In addition, if time, speed, or delay studies of existing conditions have pinpointed specific operational problems, estimates of the effectiveness of actions targetted at those problems may not be needed.

User cost estimates are generally required only under a few circumstances:

- Diversion to other routes, modes, and time periods are intended or likely to result from implementing an action.
- Transit, parking, or toll revenues are important in assessing proposed actions.

- Estimation Procedures and Methods

Most travel time estimation procedures operate at the component level; e.g., they estimate time spent at an intersection, traversing a roadway or route segment, or using a paratransit service. The procedures range from a simple division of distance by average speed to queuing or other simulation models, but most common are graphs or equations that relate time to physical dimensions, other supply and capacity measures, and/or travel volumes.

Procedures also have been developed for aggregating travel time measures for subarea, corridor, and regional studies. While these are generally network-based applications of analytical procedures, simulation procedures have been developed for analyzing certain types of options such as freeway flow controls and traffic signal networks. Suitable applications of these different techniques are shown in the following Method Selection Table, along with references to procedure descriptions and application examples.

Fares, tolls, and parking charges are either specified or obtained directly from the appropriate operating agencies. Vehicle operating costs (and other continuous costs) generally are analytically derived from or calculated in parallel with time estimates. Changes in fuel costs (i.e., fuel savings times price) will provide a sufficiently accurate estimate of auto driver savings. (Note: State and federal taxes should be subtracted from price in calculating a total or net benefit measure.) Savings to fleet vehicles such as trucks and buses should include other factors such as driver and vehicle productivity. Reference 7 contains unit cost data for trucks, and a procedure for updating those costs; bus operating costs are covered under finance measures. Network-based and other aggregation procedures can be used to sum operating costs, as well as to sum discrete costs such as tolls and transit fares.

- Travel Time and User Cost References

1. Curry, D.A. and Anderson, D.G., "Procedures for Eatimating Highway User Costs, Air Pollution and Noise Effects." NCHRP Report 133, Washington, D.C. (1972) 127 pp.

2. Homburger, W.S. (editor), Transportation and Traffic Engineering Handbook. Second edition, Institute of Transportation Engineers, Prentice-Hall Inc., Englewood Cliffs, N.J., (1982) 880 pp.

3. Box, P. and Oppenlander, J., Manual of Traffic Engineering Studies. Fourth Edition, Institute of Transportation Engineers, Arlington, Va. (1976) 233 pp.

4. JHK and Associates, Design of Urban Streets - Training Course Manual prepared for USDOT, FHWA (HHI-2). (Undated)

5. Barton-Aschman Assoc., "ESTOP Guide and Manual for Estimating Traffic Operations Benefits." Two volumes prepared for Illinois DOT (May 1981) 180 pp.

6. AASHTO, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements. Washington, D.C. (1977) 189 pp.

7. Federal Highway Administration, Traffic Control Systems Handbook. Implementation Package 76-10, FHWA office of Development, Washington, D.C. (June 1976) 650 pp.

8.* Courage, K.G. and Landmann, M.R., "Signal Operation Analysis Package (SOAP)." Volume 2: User's Manual and Volume 4: Portable Calculator Routines, report No. FHWA-IP-79-9 (HPI-21), Washington, D.C. (July 1979).

9.* Lee G.E., et al., "The TEXAS Model for Intersection Traffic - User's Guide," Research Report No. 184-3, Center for Highway Research, University of Texas, Austin, Tex. (July 1977) 100 pp.

10.* USDOT/FHWA, SIGOP-III User's Manual. Draft Report No. FHWA-1P-82-19, Washington, D.C. (July 1982), 130 pp.

11.* Wallace, C.E., et al., TRANSYT-7F User's Manual. Prepared for USDOT/ FHWA (HTO-23), Gainesville, Fla. (Feb. 1983) 500 pp.

12. Lieberman, E., "Macroscopic Simulation for Urban Traffic Management," Five volumes, prepared for USDOT/FHWA (HRT-20) (Jan. 1982) (TRAFLO Model).

13. Little, J.D.C., Kelson, J.D., and Gartner, N.H., "MAXBAND, a Program for Setting Signals on Arteries and Triangular Networks." Transportation Research Record 795, Washington, D.C. (1981) pp. 40-46

14.* Messer, C.J., Haenel, H.E., and Koeppo, E.A., "A Report on the User's Manual for Progressive Analysis and Signal System Evaluation Routine - PASSER II." Texas Transportation Institute, Research Report 165-14 (Aug. 1974) NTIS # PB 241-582.

15.* Fambro, D.B., et al., "A Report of the User's Manual for Diamond Interchange Signalization - PASSER III." Texas Transportation Institute, Research Report No. 178-1 (Aug. 1976).

16.[*] Minister, R.D., et al., "A Computer Simulation Model for Evaluating Priority Operations on Freeways." ITTE, University of California, Berkeley Calif. (1973) (PRIFRE Model) 315 pp.

17.[*] University of California, Berkeley, "Simulation of Freeway Priority Strategies (FREQ3CP), User Documentation." Prepared for USDOT/FHWA (June 1975) 250 pp.

18.[*] Transportation Research Board, "The Application of Traffic Simulation Models." Special Report No. 194, Washington, D.C. (1981) 115 pp.

19. USDOT/UMTA and FHWA, "Urban Transportation Planning System, Introduction and Operating Instructions." Washington, D.C., (periodically updated).

20. USDOT/FHWA, "PLANPAC/BACKPAC General Information," NTIS # PB-240-716, Washington, D.C. (April 1977 and updates) 440 pp.

21. Sanders, D., et al., Characteristics of Urban Transportation Systems: A Handbook for Urban Transportation Planners. Prepared by DeLeuw Cather and Company and Rock Creek Associates for USDOT/FHWA and UMTA, with contributions from the Urban Institute (July 1977).

22. Levinson, H.S., Adams, C.L., and Hoey, W.F., "Bus Use of Highways - Planning and Design Guidelines." NCHRP Report 155, Washington, D.C. (1975) 160 pp.

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[*] Reference 18 reports the proceedings of a conference on traffic simulation models. Selected papers describe and compare the capabilities and limitations of several models (including those marked with asterisks above), and cite additional manuals and application reports.

Method Selection Table 2: Travel Time Estimation

2

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
Spot or Segment Analysis		
● Vehicular delays at intersections		
- check for acceptable level-of-service	- use capacity adequacy techniques cited in the Methods Selection Table for Supply/Capacity estimation	
- estimate average travel time, delay or queue duration	- apply analytical techniques and worksheets	1-5
	- apply simulation models of signalized intersection operations (mainly applicable to complex, high-volume intersections)	8,9
- set signal timing to minimize delays	- apply Webster's equation or similar procedure	7
● Vehicular travel time along roadway segment		
- check for acceptable level-of-service	- use capacity adequacy techniques cited in the Methods Selection Table for Supply/Capacity estimation	
- estimate average travel time	- use curves relating speed to volume/capacity ratio for different types of roadways	1,6 see TN #3
● Travel time along transit route segment	- apply an analytical procedure to calculate route segment running times	see TN #4
	- use average operating speeds observed under similar conditions	21,22, see Profile Sheets for transit actions
Subarea Analysis		
● Vehicular travel times along important routes		
- estimate average travel time or delay	- apply intersection and segment techniques in series	10-12
	- apply arterial or network simulation model (e.g., SIGOP, TRANSYT or TRAFLO)	
- set signal operations to achieve desired or least travel time	- apply techniques that maximize band width (e.g., MAXBAND or PASSER)	13-15
	- apply techniques that minimize stops and delays (e.g., SIGOP or TRANSYT)	8,9
● Aggregate or average vehicular travel time		
- estimate total or average user travel time or delay	- apply computerized network assignment analysis package (e.g., UTPS or PLANPAC)	19,20
	- apply macroscopic simulation model (e.g., TRAFLO)	12
● Travel time along a transit route	- apply route segment analysis procedure	See TN #4
	- use average operating speeds observed under similar conditions	21,22

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* For numbered references, refer to text section of Method Selection Aid #2. Tech. Notes cited may be found in the Notes on Selected Techniques Section.

2 Method Selection Table 2: Travel Time Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
Subarea Analysis (continued)		
● Aggregate or average transit travel time		
- riders	- apply network analysis package (e.g., UTPS)	19
	- manually assign trips to estimate average length, then apply average operating speed	21,22
- buses	- add vehicle-miles on each route, and apply average operating speeds to estimate vehicle-hours	21,22
	- apply network analysis package (e.g., UTPS)	19
● Point-to-point travel times	- use above techniques to estimate in-vehicle travel time, then add other components such as walking, waiting and search for parking	
Corridor Analysis		
● Vehicular travel times		
- estimate effects of physical, operational or volume changes along a signalized artery	- apply a macroscopic simulation package (e.g., (TRAFLO) or a signal optimization package (e.g., SIGOP or TRANSYT)	10,11,12
- estimate effects of physical, operational or volume changes along a unsignalized artery	- apply intersection and segment techniques in series	
- estimate effects of physical, operational or volume changes along a freeway	- apply segment techniques in series	
	- apply a macroscopic simulation model (e.g., FREQ or PRIFRE)	16,17
- estimate effects of physical, operational or volume changes throughout corridor	- apply a computerized network assignment and analysis package (e.g., UTPS or FHWA/PLANPAC)	19,20

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* For numbered references, refer to text section of Method Selection Aid #2. Tech. Notes cited may be found in the Notes on Selected Techniques Section.

Method Selection Aid 3: Estimating Safety Characteristics

- General

TSM actions often are directed at solving or alleviating accident problems; examples include intersection redesign, traffic signalization, parking restrictions, street lighting, and one-way streets. The principal means of expressing safety changes are:

- Increase/decrease in number of accidents or accident rate.
- Increase/decrease in hazard level or accident exposure.

- Conditions for Estimation

"Estimates" of changes in safety are required at locations where accidents are a major problem and proposed actions may significantly reduce the potential for accidents. Because of the statistical difficulty in accurately estimating critical differences in accidents (or rates) for actions that produce minor to moderate changes, accidents need not be estimated for most projects. Instead, detailed analysis of existing accidents combined with actions targetted at their causes (e.g., left-turn conflicts or visual obstructions) generally will ensure that the problems have been addressed. Accident rates or reduction factors observed for similar improvements (e.g., using before-after studies) also may be used to estimate an action's potential effectiveness.

Analysis of safety change also may be desirable for certain other actions, such as reversible or 2-way left-turn lanes implemented to improve traffic flow. Again, analysis needs usually can be met by applying design standards or sound engineering practice to ensure that safety problems are not introduced.

- Estimation Procedures and Methods

Accident problems are localized; they occur at specific locations such as an intersection, road segment, rail grade crossing, bridge, or transit stop. They generally have little meaning on a large geographic basis or for an entire facility. Accordingly, accident/hazard information must be examined on a localized, site-specific basis. While broad scale corridor and regional safety change estimates can be developed using typical rate values applied to vehicle-miles, car-miles, or person-miles of travel, this information is not helpful for most TSM project evaluations. An exception would be a policy analysis of the safety impacts of changes in vehicle inspection or traffic enforcement programs.

The suggested methods shown in the following Method Selection Table are organized to support three major steps in a safety analysis:

- The use of reported accident rates or field observations to determine the severity of a safety problem.
- The detailed examination of a problem location (including accident reports) to determine factors that cause the safety problem.
- The determination of the adequacy or effectiveness of proposed actions in solving or avoiding safety problems.

- Safety References

1. Homburger, W.S. (editor), Transportation and Traffic Engineering Handbook. Second Edition, Institute of Transportation Engineers, Prentice-Hall Inc., Englewood Cliffs, N.J., (1982) 880 pp.
2. Box, P. and Oppenlander, J., Manual of Traffic Engineering Studies. Fourth Edition, Institute of Transportation Engineers, Arlington, Va (1976) 233 pp.
3. Glauz, W.D. and Migletz, D.J., "Application of Traffic Conflict Analysis at Intersections." NCHRP Report 219, Washington DC (Feb. 1980) 110 pp.
4. U.S. Department of Transportation, Model Pedestrian Safety Program User's Manual. Implementation Package 78-6, Washington, D.C. (1978) 268 pp.
5. McFarland, W.F., et al., "Assessment of Techniques for Cost-Effectiveness of Highway Accident Countermeasures." USDOT Report No. FHWA-RD-79-53, Texas Transportation Institute, College Station Tex. (Jan. 1979) 350 pp.

3 Method Selection Table 3: Safety Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
<u>Spot or Segment Analysis</u>		
● Determining relative severity of accident problems	- compare accident rates with averages compiled for road classification (many state DOT's periodically summarize accident data by severity (i.e., fatal, injury producing, property damage only; land use - e.g., urban, suburban, rural; and highway class - e.g., freeway, major arterial, minor arterial, collector)	1
	- use critical rate method to test for statistical significance of calculated rates (accidents are rare events, so site-specific rates are often unreliable indicators of a problem, particularly on low volume roads)	1, 2 See TN #2
	- conduct field studies of traffic conflicts (Observations may pinpoint the causes of accidents and indicate safety problems that produce few accidents, possibly as a result of extra driver caution)	2,3 1,2
● Detailed examination of probable accident causes	- prepare collision diagrams from accident reports	19
	- conduct behavioral analysis of driver actions as related to conditions at location	4
● Determination of effectiveness of proposed solutions	- use results of studies showing effects of implemented actions at similar locations	5, See TN #7
	- apply "sound engineering practice" to reduce conflicts causing accidents	1, 2
<u>Subarea or Corridor Analysis</u>		
● Summarize problems	- prepare spot map showing problem locations and number of incidents at each	1
● Any type of analysis	- conduct as a series of spot and segment studies using methods cited above	

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* For numbered references, refer to text section of <u>Method Selection Aid #3</u>. Tech. Notes cited may be found in the <u>Notes on Selected Techniques</u> Section.

Method Selection Aid 4: Estimating Travel Volumes

4

- General

Despite TSM's near-term focus, implemented actions may have to accommodate changes in travel expected as a result of continued growth, changes in land use, or increased density of development. TSM actions also may be designed to influence individuals' travel choices, or may result in service quality changes that have that effect. These travel choices include:

- Increase or decrease in the number of trips taken.
- Shifts in the destination of trips.
- Shifts among the modes used for travel.
- Shifts in the routes chosen for trips.
- Shifts in the timing of trips.

The travel volume changes of interest in an analysis usually are limited by the small scale or narrow focus of the actions themselves. In a particular assessment, an analyst will be concerned primarily with travel on specific facilities, to, from, or within specific areas; on specific modes, during specific time periods, for specific purposes, or by certain segments of the population. Typical examples are:

- Change in peak-hour vehicle volumes along an arterial street (by direction).
- Number of autos entering a proposed office park in the morning peak.
- Change in daily boardings on a transit route.
- Change in midday occupancy rate of off-street parking.
- Change in peak vehicle occupancy on a freeway;
- Change in systemwide weekend transit ridership.

- Conditions for Estimation

Travel volumes may have to be estimated in a variety of situations. The more common are:

- Growth or land-use changes are expected in or near the study area, or along travel routes passing through the area (e.g., the construction of an office park or shopping center).

- Proposed actions may change the relative attractiveness of different modes for trips to, in, or through the study area (e.g., a new express bus, increases in transit fares, or increased parking charges).

- Proposed actions may change the relative attractiveness of travel routes to, in, and through the study area (e.g., the metering of freeway entrance ramps, improved signal coordination or parking bans along major arterial streets, or the blockage of routes through a retail or residential area).

- Proposed actions may increase travel by certain segments of the population (e.g., a new elderly or handicapped transit service, weekend transit operations, or the elimination of transit fares for travel within the CBD).

- Proposed actions may affect the relative attractiveness of travel at different hours (e.g., off-peak parking and transit fare reductions, or staggered or flexible working hours).

Only a few of these conditions will apply in most TSM analyses, and in many of those cases the conditions will be limited to selected facilities, routes, and/or travellers. An estimation of volume changes, therefore, should be carefully planned to avoid unnecessary efforts.

Answers to the following questions will help define an appropriate scope for an analysis:

- Which transport facilities or services are likely to be affected by proposed actions or developments?

- Which (types of) trips and travellers are likely to be affected?

- How significant are proposed or expected service quality changes in terms of total journey travel times and costs?

- Will saturated flow conditions on roadways in or approaching the study area continue to limit entering travel volumes?

- How large a volume change is necessary before design changes are required, or before a problem is created or resolved?

- At what scale will the expected volume changes affect any derived measures important in the actions' evaluation?

- At what scale will the expected volume changes be observable after the proposed actions have been implemented?

A few examples will help illustrate the use of these "screening" questions:

1. A 30-second reduction in travel time will not be noticed by travellers making trips even as short as 10 minutes and, therefore, is unlikely to have any effect of travel demand or volumes.

2. A large parking fee increase in the CBD may divert drivers to transit or carpools, reducing the number of autos entering the area. Changes in traffic at individual intersections, however, may not be measurably affected. Similarly, increased crowding may be noticeable only on a few high volume bus routes, even though total ridership into the CBD increased.

3. A regionwide transit fare increase will reduce ridership, and the change probably will be noticeable on individual routes. Changes in auto volumes, however, will only be noticed across a few screenlines where transit ridership is very high.

4. A 1/2-mile transit mall probably will not affect auto or transit journey times and mode choices. Auto traffic will be displaced, and volumes (including turning movements) on nearby streets may noticeably increase.

In general, local service changes will produce no volume impacts beyond a few local auto routing decisions (resulting, for example, from turn prohibitions or one-way street segments) or choice of bus stop (resulting, for example, from stop relocations or minor routing changes). Conversely, regionwide changes in auto travel are unlikely to be produced by TSM actions.

Corridor and subarea changes, in contrast, may produce varied and complex volume responses. In analysis at these scales, care should be taken to determine:

- Which volume changes are important for making design and operational decisions.
- Which decisions can be based on aggregate estimates (e.g., cordon crossings).
- If and where detailed estimates (e.g., intersection, route, or parking garage volumes) are needed.

Estimation Procedures and Methods

Volume estimation in TSM planning usually entails the estimation of changes from existing conditions; exceptions include the introduction of specialized transportation services and the expansion of transit into new areas. As a result, estimation often can be based on data collected through traffic counts, transit ridership counts, user surveys, and similar techniques. Where data cannot be collected directly, information from similar sites or reported in the planning literature can provide analogies.

Where models are applied in estimation (e.g., a corridor traffic assignment or mode choice analysis), a "pivot-point" approach often can be taken. This involves applying a technique to both existing and proposed conditions, and using the percentage or absolute change predicted by the technique as the change expected from observed base conditions. In general, this approach should be used to avoid model errors and extensive calibration efforts to match model estimates with observed conditions.

The following Method Selection Table cites a variety of techniques, particularly for corridor or subarea analyses. In many cases, techniques should be used in sequence, or the results of two or more techniques should be combined. For example, trips to a new development estimated using attraction rates might be added to a trend-line extrapolation (of existing trips) performed to account for forecast population growth.

Travel Volume References

1. USDOT/FHWA, "Purposes of Vehicle Trips and Travel." National Personal Transportation Study, Report 3 (1980)

2. Arizona DOT, "Trip Generation Intensity Factors (TGIF)." Reported by USDOT/FHWA, Washington, D.C. (June 1977) 400 pp.

3. Institute of Transportation Engineers, "Trip Generation." Informational Report, Arlington Va. (1976) 250 pp.

4. Levinson, H.S., "Characteristics of Urban Transportation Demand, A Handbook for Urban Planners." Prepared by Wilbur Smith and DeLeuw Cather for USDOT/ UMTA, Report No. UMTA-IT-06-0049-78-1, New Haven, Conn. (April 1978) 130 pp.

5. Mayworm, P.D., Lago, A.M., and McEnroe, J.M., Patronage Impacts of Changes in Transit Fares and Service. Prepared for USDOT/UMTA UPM-33 by Ecosometrics, inc., Contract No. DOT-UT-90014 (Sept. 1980) 247 pp.

6. Barton-Aschman Assoc., Inc., Traveler Response to Transportation System Changes, Second Edition. Prepared for USDOT/FHWA, Office of Highway Planning, Contract No. DOT-FH-11-9579 (July 1981) 400 pp.

7. Atherton, T.J. and Suhrbier, J.H., "Urban Transportation Energy Conservation." Volume III: Case City Applications of Analysis Methodologies, prepared for USDOE, Report No. DOE/PE/8628-1, Cambridge, Mass. (Oct. 1979) 140 pp.

8. Gilbert, K., "Transportation Systems Management: Handbook of Manual Techniques for Transit Strategies." Prepared for North Central Texas Council of Governments (1977), distributed by USDOT/ UMTA, Report No. TX-09-0045-81-1 (1981) 200 pp.

9. Sosslau, A.B. et al., "Quick-Response Urban Travel Estimation Techniques and Transferable Parameters, User's Guide." NCHRP Report 187, Washington, D.C. (1978) 230 pp.

10. Multisystems, Inc., "Route Level Demand Models: A Review." Prepared for USDOT/UMTA, Report No. DOT-I-82-6, Cambridge, Mass. (Jan. 1982) 65 pp.

11. Billheimer, J.W., et al., Paratransit Handbook, A Guide to Paratransit Implementation. Report Nos. UMTA-MA-06-0054-79-1 and -2, Systan, Inc., Los Altos, Calif. (Jan. 1979) 828 pp.

12. Peat, Marwick, Mitchell and Co., "Analyzing Transit Options for Small Urban Communities." Volume 3: Summary of Management and Operations Experience, Report No. UMTA-IT-06-9020-78-3, Washington, D.C. (Jan. 1978) 175 pp.

13. Golenberg, M. and Howard, J.A., "Lewiston CBD Subarea Study: A Short Range TSM Subarea Planning Case Study." Prepared for USDOT/FHWA and UMTA under Contract No. DTFH61-80-0071, Boston, Mass. (Sept. 1982) 75 pp.

14. USDOT/FHWA, "Urban Transportation Planning System, Introduction and Operating Instructions." Washington, D.C., (periodically updated)

15. USDOT/FHWA, "PLANPAC/BACKPAC General Information." NTIS #PB-240-716, Washington, D.C. (April 1977 and updates) 440 pp.

16. Pederson, N.J. and Samdahl, D.R., "Highway Traffic Data for Urbanized Area Project Planning and Design." NCHRP Report 255, Washington, D.C. (Dec. 1982) 190 pp.

17. Simpson and Curtin, Guidelines for Traffic Impact Study. Prepared for Virginia Department of Highways (April 1979)

18. Golenberg, M. and Howard, J.A., "Town of Hudson Subarea Traffic Study: a Major Capital Improvement Subarea Planning Case Study." Prepared for USDOT/FHWA and UMTA under contract DTFH61-80-0071, Boston, Mass. (Sept. 1982) 90 pp.

19. Multiplications, Inc., "Bus Route Planning Models." Draft report prepared for USDOT/TSC and UMTA under contract no. DOT-TSC-1756 Cambridge, Mass. (April 1983) 90 pp.

20. Homburger, W.S. (editor), Transportation and Traffic Engineering Handbook. Second Edition, Institute of Transportation Engineers, Prentice-Hall Inc., Englewood Cliffs, N.J. (1982) 880 pp.

4 Method Selection Table 4: Travel Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
<u>Spot or Segment Analysis</u>		
● Vehicles using road segment or intersection		
- any case where overall growth is expected in corridor	- adjust existing counts using trend-line growth factor derived from historical counts or from population or vehicle registration trends. (base year and forecast network traffic assignments prepared for the corridor or region also may be used)	16,17
- any case near proposed land development	- use trip rate factors to estimate new trips to/from the development;	1-3,9,17
	then manually distribute and assign the trips to determine the facility's share	9,16
- operational changes (e.g., turn prohibitions, curb cut closures, parking relocation	- manually reassign traffic affected by the proposed changes	16,17
● Transit boardings or alightings at stop or along segment		
- any case near proposed land development	- use transit trip rate factors or mode shares to estimate new trips (factors or shares should be based on similar land uses and similar service levels)	
- operational changes (e.g., bus stop relocation, minor rerouting)	- link boarding/alighting counts with land uses and intersecting transit routes, and reassign trips based on walking distance to proposed stops.	
<u>Subarea Analysis (Aggregate Volumes)</u>		
● Person trips to or from subarea		
- any case where new development is proposed in subarea	- apply trip rate factors to estimate trip productions or attractions for the time period, trip purpose or population group of interest	1-4,9,17
	- scale existing trip ends using percentage growth in population, employment or retail floor space	see TN #1
- population growth is expected in areas served by a commercial center	- scale existing trip ends using percentage growth in population	
● Transit ridership to or from subarea		
- growth or development expected in or near subarea	- apply techniques used to estimate change in person trips (i.e. assume mode shares will not change)	
- changes in fares, service frequencies, or parking fees	- apply elasticities to existing ridership counts	5, 6 See TN #5
	- use a pivot-point application of a mode share model to estimate changes in ridership in different market segments (e.g., long vs. short peak period trips) of interest	7, 8

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* For numbered references, refer to text section of <u>Method Selection Aid #4</u>. Tech. Notes cited may be found in the <u>Notes on Selected Techniques</u> Section.

Method Selection Table 4:
Travel Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
<u>Subarea Analysis (Aggregate Volumes)</u> (continued)		
- new transit routes or services between subarea and other areas	- use ridership on similar routes or services as an approximation for new ridership	6
	- base estimate on "riding habit" (e.g., riders per capita) in areas with similar demographic and service characteristics	12
	- apply a mode share model to market segments served by the new routes	8,9
	- apply a direct demand model to estimate new ridership	10,19
● Total transit ridership within subarea		
- changes in fares or service frequencies (e.g., CBD fare-free zone)	- apply elasticities to existing ridership counts	5, 6
	- use results of similar changes to estimate ridership	6
- new circulation or community-based transit services	- base estimate on ridership on similar services in similar areas	11,12
● Auto vehicle trips entering or leaving subarea		
- new development is proposed in subarea	- separate existing cordon counts into subarea and through trips; then apply percentage growth in population, employment or retail floor space to subarea trips	16,18
	- apply trip rate factors to estimate new trips by time-of-day	1-4,9,17,20
- population growth is expected in areas served by a commercial center	- scale existing cordon counts using anticipated population growth rate in each area; then manually distribute trips to estimate portion passing through the analysis subarea	16
- development is expected in nearby area	- apply trip rate or growth factors to estimates trips to or from the new development (after separating through trips as above)	16
- time or fee incentives for carpool users proposed in subarea or along approach corridors	- use pivot-point application of a mode share model to estimate changes in auto drivers in different market segments	7
	- use changes reported in similar cases as an approximation	
- major changes in parking fees or availability in subareas with good transit service	- apply mode share models, as above	7
	- use similar cases as analogies	See Profile Sheets
- major changes in transit service or fares in subareas with good transit service	- apply mode share models, as above	7
	- use similar cases as analogies	5,6

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* For numbered references, refer to text section of <u>Method Selection Aid #4</u>. Tech. Notes cited may be found in the <u>Notes on Selected Techniques</u> Section.

4 Method Selection Table 4: Travel Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
Subarea Analysis (Aggregate Volumes) (continued)		
- auto service quality changes designed to divert through trips	- manually reassign traffic flows affected by the changes	16
	- use computerized assignment procedure to reassign traffic in and near subarea after parameters have been validated using existing cordon or screen line counts	16
● Autos parked in subarea		
- residential parking permits or bans	- use results of similar actions as analogies	See Profile Sheets
	- use license plate survey of parked cars to estimate % non-resident	
- other changes	- derive estimate in parallel with changes in "auto vehicle trips entering subarea"	
● Pedestrians or cyclists entering, leaving or travelling within subarea		
- new development within subarea	- scale existing counts	
- improvements to access and circulation routes for cyclists and pedestrians	- use volumes observed under similar conditions	
Subarea Analysis (Detailed Volumes)		
● Vehicles parking in zone or facility		
- changes in parking policy or operations (e.g., time limits or bans)	- adjust existing parking counts by manually reasigning affected autos	
- new development planned in subarea	- distribute new auto trip ends among zones or facilities within walking distance	
- changes in auto trip ends resulting from growth outside subarea	- scale parked auto counts by percentage change in total entering autos during appropriate time period (e.g., AM peak trips for all-day parking); manually reassign autos where parking capacity is exceeded	
- changes in auto trip ends resulting from changes in parking fees or in carpool or transit service quality	- scale parked auto counts and adjust as above; reassign autos nearer to major destinations if excess capacity develops	
● Vehicles using a street or intersection		
- changes in street operations or parking policy in a small subarea (e.g., town center, office park or redidential community)	- adjust traffic counts by manually reassigning affected flows	9,17
	- prepare synthetic trip distribution using existing traffic and parking counts; then reassign flows in response to proposed changes	13

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* For numbered references, refer to text section of Method Selection Aid #4. Tech. Notes may be found in the Notes on Selected Techniques Section.

Method Selection Table 4:
Travel Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
Subarea Analysis (Detailed Volumes) (continued)		
- changes in street operations or parking policy in a large subarea (e.g., CBD or other regional center)	- apply manual techniques cited for use in a small subarea	
	- apply computerized traffic technique, such as FHWA/PLANPAC, to a detailed subarea network	14,15,18
● Boardings or loads on transit route segments		
- route modifications in subarea	- use boarding/alighting counts to distribute existing trips among stops or zones in subarea; then manually reassign affected trips to new boarding or alighting points	
- fare or large parking fee change	- scale existing counts by estimated percentage change in transit trips entering subarea, applying different factors to different trip purposes or time periods.	5, 6 see TN #5
- new development in subarea	- distribute new trips among routes in proportion to existing ridership into the subarea; then assign new trips to stop on route nearest development	
Regional Analysis (Aggregate Volumes)		
● Transit ridership		
- fare changes	- apply peak and off-peak fare elasticities to obtain rough estimate of ridership changes	5, 6 see TN #5
- coverage	- apply vehicle-mile elasticities to obtain rough estimate of ridership changes	5, 6 see TN #5

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* For numbered references, refer to text section of Method Selection Aid #4. Tech. Notes cited may be found in the Notes on Selected Techniques Section.

Method Selection Aid 5: Estimating Financial Characteristics

- General

In addition to implementation or capital costs, a TSM package may increase or decrease system operating and maintenance costs and revenues. Examples are transit fare changes, route expansions, revised parking policies, HOV lanes, and ramp meters. Packages that include new or greatly expanded services or programs (e.g., community transit, carpool matching, or parking permits) also may result in new or increased administrative costs.

- Conditions for Estimation

The financial implications of a proposed TSM package on an energy must be considered in evaluating the package, and estimates of specific costs or cost changes should be prepared if they are likely to have a significant impact on the agency's capital or operating budgets. Impacts on other agencies' budgets also should be estimated, such as the need for additional police to enforce priority or traffic control measures. Cost estimates also are required if the package is subject to a cost/effectiveness or benefit/cost assessment as part of evaluation or priority programming activities.

Estimates of revenues of revenue changes are required if fee, fare, or toll increases are part of a TSM package, or if the use of facilities or services on which they are collected is expected to change as a result of implementing the package.

- Estimation Procedures and Methods

Cost estimates for many service and facility changes can be prepared by deriving unit costs (e.g., annual maintenance costs per lane-mile, parking space or per bus) from agency records and applying those costs to proposed changes in supply characteristics. Unit costs derived from similar facilities and operations are preferable to systemwide averages because substantial differences may exist (e.g., between express and local buses and between major arterial streets and collectors). Care should be taken to exclude fixed or overhead costs when the unit costs are to be used to evaluate small changes.

Other good sources for cost information are (1) published summaries of operating data such as the CUTS handbook (1) and the APTA Fact Book (2), and reports describing the implementation and operation of specific TSM actions, such as the UMTA/SMD evaluation series.

Sources of cost information and methods are presented in the following Method Selection Table. The user also should refer to the appropriate profile sheets for sources on specific types of actions.

Cost estimates may have to be factored to account for regional differences and/or inflation. Several escalation and inflation indices are published; their sources are listed in Tech. Note #6.

Revenues and revenue changes generally are calculated directly from use estimates and specified fees. Net operating costs, subsidy requirements, and cost recovery ratios (all derived from revenue and cost estimates) also are useful measures for evaluating impacts on transit and parking operations.

- Financial References

1. Sanders, D., et al., Characteristics of Urban Transportation Systems: A Handbook for Urban Transportation Planners. Prepared by DeLeuw Cather and Company and Rock Creek Associates for USDOT/FHWA and UMTA, with contributions from the Urban Institute, (July 1977).

2. American Public Transit Association, Transit Fact Book. Washington, D.C., (Published Annually)

3. USDOT/UMTA, National Urban Mass Transportation Statistics, Section 15 Reporting System. Report No. UMTA-MA-06-0107-82-1 (July 1982) 400 pp.

4. Simpson and Curtin, Bus Route Costing Procedures, a Review. USDOT/UMTA, Report No. UMTA-IT-09-9014-81-1 (May 1981)

5. Gilbert, K., "Transportation Systems Management: Handbook of Manual Techniques for Transit Strategies." Prepared for North Central Texas Council of Governments (1977), distributed by USDOT/ UMTA, Report No. TX-09-0045-81-1 (1981) 200 pp.

6. Batchelder, J.H., et al., "A System Analysis of Transit/Paratransit Integration." Volume 5: User's Manual for the MMARS/MMACS Package, prepared by Multisystems for USDOT/UMTA, Contract No. DOT-UT-80007 (Sept. 1980) 280 pp.

Method Selection Table 5: Financial Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
<u>All Scales of Analysis</u>		
● Project-level analysis of capital, operating, maintenance and administrative costs:		
- roadway capacity and flow changes	- component costing or engineering cost analysis; i.e., applying unit costs to components (e.g., signals, linear feet of curbing) and summing	
- transit service changes	- allocated cost models; i.e., changes procedures that allocate line item, marginal costs to supply measures such as vehicles, vehicle-hours and vehicle-miles	4,5,6
	- component costing, applied to estimates of changes in driver requirements and/or other supply measures	4
- new facilities, services or operating policies	- analogy; adapt results reported for similar actions	see Profile Sheets for references
- all actions	- use escalation factors or indices to convert cost estimates to constant dollars	see TN #6
● Project-level revenue estimation:		
- all actions	- direct calculation from fares and users by fare category	
● "Ball-park" estimation of capital, operating and maintenance costs, or validation of project estimates	- analogy, compare with summary statistics compiled from similar operations	1,2,3

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* For numbered references, refer to text section of <u>Method Selection Aid #5</u>. Tech. Notes cited may be found in the <u>Notes on Selected Techniques</u> Section.

Method Selection Aid 6: Estimating Air Quality Impacts

- General

Air quality impacts are difficult to estimate directly because they are affected by weather, wind patterns, structures, and nontransportation sources of pollutants. Consequently, vehicular emissions or changes in emissions usually serve as surrogate measures in air quality evaluations, with estimation limited to the three types that have the greatest impact on air quality: carbon monoxide, nitrogen oxides, and hydrocarbons.

- Conditions for Estimation

Estimates of changes in air pollutant emissions clearly are required if a TSM package is designed to address an air quality problem. Estimates also are desirable if (1) air quality is near or below standards and (2) a subarea, corridor or regional TSM package is likely to increase vehicular volumes or degrade traffic flow conditions on important roadways. Estimates also may be desirable to show that a package conforms to regional air quality improvement objectives, but measures of improved traffic flow or decreased vehicular travel should be sufficient in these cases.

- Estimation Procedures and Techniques

The basis for estimating changes in pollutant emissions is a model developed by the USEPA (1). Other researchers have taken these relationships and prepared graphs, tables, and other simplified estimation procedures; they also have been included in many network analysis and traffic flow simulation models. Some of these are cited in the Method Selection Table, but with the following caveat: they all depend heavily on assumptions regarding fleet mix (i.e., the composition of the current fleet in terms of vehicle size and year of manufacture). Vehicle sizes and emission rates have changed dramatically during the last decade and will continue to change; therefore, values estimated using those procedures should be used with caution. Estimates of percentage changes in emissions generally will be usable, but estimates of emission volumes or changes in volumes will be exaggerated unless they are updated. The FHWA has applied the basic EPA model over a range of analysis years and operating conditions, and has produced a set of tables that can be applied to update emission estimates (2). The use of the tables is illustrated in Tech. Note #9.

- Air Quality References

1. USEPA, "User's Guide to MOBILE 2 (Mobile Source Emissions Model)." Report No. EPA-460/3-81-006, NTIS No. PB81-205619, Ann Arbor, Mich. (Feb. 1981) 420 pp.
2. USDOT/FHWA, "Mobile Source Emission Factor Tables." Technical Advisory Memorandum T6640-1 (Nov. 16, 1978) 140 pp.
3. Dale, C.W., Procedure for Estimating Highway User Costs, Fuel Consumption and Air Pollution. USDOT/FHWA, NTIS No. PB80-159957, (March 1980) 46 pp.,
4. Ismart, D., "Mobile Source Emissions and Energy Analysis at an Isolated Intersection." Transportation Research Record 842, Washington, D.C. (1982) pp. 5-10
5. Barton-Aschman Assoc., "ESTOP Guide and Manual for Estimating Traffic Operations Benefits." Two volumes prepared for Illinois DOT (May 1981) 180 pp.
6. Raus, J., A Method for Estimating Fuel Consumption and Vehicle Emissions on Urban Arterials and Networks. FHWA, Office of Research and Development, Report No. FHWA-TS-81-210 (April 1981) 55 pp.

Method Selection Table 6: Air Quality Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
Spot or Segment Analysis		
● Emissions at an intersection or along a road segment		
- test for problem developing as a result of volume or service quality change	- apply graphs and equations to calculate percentage changes resulting from increased volumes, idling, or number of speed changes or stop cycles	3,4,6
- determine if proposed actions will eliminate local hot-spot	- estimate percentage change as above, and apply to current meter readings to assess adequacy of actions	3,4,6
	- apply graphs and equations to calculate changes in emissions; use tables to update estimates from 1975 (or other base year)	3-6 2 See TN #9
Subarea or Corridor Analysis		
● Emissions along major roadways		
- test for a potential problem	- apply graphs and equations to estimate percentage changes at intersections or segments where volumes or delays are expected to increase	3,4,6
	- examine estimates produced by a network analysis or simulation model	see Travel Time table
- estimate changes resulting from proposed actions	- apply manual methods in a series of spot and seg- analyses	3-6
	- apply network analysis or simulation models	see Travel Time table
	- in either case, update estimates to analysis year	2, see TN #9
● Total corridor or subarea emissions		
- estimate changes resulting from proposed actions	- apply computerized network models to obtain preliminary estimates; update estimates to analysis year	see Travel Time Table 2, see TN #9

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* For numbered references, refer to text section of Method Selection Aid #6. Tech. Notes cited may be found in the Notes on Selected Techniques Section.

Method Selection Aid 7: Estimating Energy Use

- General

The energy consumed in providing transportation is one of the direct operating costs borne by the user or operator. In recent years, energy consumption also has come to be viewed as a societal cost, with reductions in consumption enhancing the nation's independence, security, and economic health.

- Conditions for Estimation

Changes in energy use need to be estimated only when reduction is a primary objective of a TSM package or program. Estimates also may be desirable to show that a package conforms to state or national objectives, but direct measures such as reductions in idling, speed change cycles, or vehicle volumes should provide sufficient evidence.

- Estimation Procedures and Techniques

The basic parameters affecting fuel consumption in a TSM analysis are the number of vehicles, travel distance, running speed, frequency of deceleration and acceleration, and idling time. Many simplified techniques that include these parameters are available in the form of equations, graphs, and worksheets, and are cited in the following Method Selection Table. (Energy consumption equations also are incorporated in many of the models cited in the travel time methods table.) These methods all have the basic problem of the simplified air quality estimation techniques. They depend heavily on assumptions regarding the mix of vehicle weights and efficiencies, factors that have changed radically over the past decade and continue to change. As a result, the techniques work best in estimating percentage changes in energy consumption; their unadjusted application to estimate use or savings will produce inflated values. Adjustment factors have been developed for updating estimates (5), and are reproduced in Tech. Note #8.

- Energy Use References

1. AASHTO, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements. Washington, D.C. (1977) 189 pp.
2. Dale, C.W., Procedure for Estimating Highway User Costs, Fuel Consumption and Air Pollution. USDOT/FHWA, NTIS No. PB80-159957 (March 1980) 46 pp.
3. Ismart, D., "Mobile Source Emissions and Energy Analysis at an Isolated Intersection." Transportation Research Record 842, Washington, D.C. (1982) pp. 5-10
4. Barton-Aschman Assoc., "ESTOP Guide and Manual for Estimating Traffic Operations Benefits." Two volumes prepared for Illinois DOT (May 1981) 180 pp.
5. New York State DOT Transportation Data and Analysis Section, "Energy Impacts of Transportation Systems Management Actions." Prepared for USDOT/UMTA Report No. DOT-I-82-4, Albany, N.Y. (October 1981) 280 pp.
6. Gilbert, K., "Transportation Systems Management: Handbook of Manual Techniques for Transit Strategies." Prepared for North Central Texas Council of Governments (1977), distributed by USDOT/UMTA, Report No. TX-09-0045-81-1 (1981) 200 pp.
7. Raus, J., A Method for Estimating Fuel Consumption and Vehicle Emissions on Urban Arterials and Networks. FHWA, Office of Research and Development, Report No. FHWA-TS-81-210 (April 1981) 55 pp.

Method Selection Table 7: Energy Use Estimation

Scale and Type of Analysis	Appropriate Techniques	References/ Tech. Notes*
Spot or Segment Analysis		
● Energy consumption at an intersection or along a road segment		
- estimate likely changes	- apply graphs or worksheet to estimate effects of volume, speed or delay changes;	1-5
	update estimates to analysis year	1,2 see TN #8
● Energy consumption along a transit route segment		
- estimate likely changes	- apply graph to estimate effects of speed changes	6
Other Scales		
● Vehicular energy consumption		
- estimate approximate changes	- apply network or simulation models to obtain preliminary estimates of change in energy use; update change to analysis year	see Travel Time tables see TN #8
	- apply worksheets to estimate change in energy use; update to analysis year	5 see TN #8

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* For numbered references, refer to text section of Method Selection Aid #7. Tech. Notes cited may be found in the Notes on Selected Techniques Section.

Notes On Selected Techniques

The technical notes on the following pages present selected techniques that are generally not available to agencies but are useful in many aspects of TSM planning. They contain both common and innovative methods for assessing key factors such as travel time, safety, and transit service needs.

In most cases, example applications are presented that illustrate the use of the techniques in planning TSM projects. Numbers in these examples are intentionally presented with only 2 or 3 significant digits (e.g., 2600 vs. 2582) because the simplified techniques and data used for analysis generally cannot support more detail.

Notes are provided on the following techniques:

1. Simplified Trip Distribution
2. Critical Accident Rate Factor
3. Speed-Volume Tables
4. Transit Supply Estimation Procedure
5. Transit Service and Fare Elasticities
6. Inflation and Escalation Indices
7. Accident Reduction Factors
8. Fuel Consumption Adjustment Factors
9. Emission Rate Adjustments
10. Critical Lane Analysis
11. Queue Length Analysis

Tech. Note 1: Simplified Trip Distribution

1

• Purpose

Transportation planning for a central business district or other major activity center often requires estimation of trips to the center from outlying areas. These estimates readily can be made if the following information is available:

- Existing population in outlying district (e.g., inner suburbs of the eastern corridor).
- Estimated population in outlying district.
- Existing trips from each district into the region to the activity center.
- Estimated level of trips to activity center.

The following simplified trip distribution model can be used to estimate travel to the activity center (by district of origin):

$$TRP_i^a = \frac{\left[\dfrac{POP_i^a}{POP_i^b} \; TRP_i^b\right]}{\sum\limits_j \left[\dfrac{POP_j^a}{POP_j^b} \; TRP_j^b\right]} \sum_j TRP_j^a \qquad (1\text{-}1)$$

where

TRP = number of trips from a district to the activity center

POP = population of a district

i = district of interest

$\sum_j$ = summation over all outlying districts

b = base year conditions

a = analysis year conditions (e.g., after growth and development have occurred)

• Example Application

The following table shows existing travel from three districts to an activity center, the likely population changes in each district, and the expected changes in total trips to the center. Using the center trips as a "control," it is desired to find the future trips from each district.

	-----Population-----		--Trips to Center--	
District	Existing	Estimated	Existing	Estimated
1	10,000	12,000	5,000	-
2	20,000	22,000	10,000	-
3	12,000	24,000	7,000	-
Total	42,000	58,000	22,000	30,000

The denominator of the distribution equation is calculated as:

$$\left[\frac{12{,}000}{10{,}000}(5{,}000)\right] + \left[\frac{22{,}000}{20{,}000}(10{,}000)\right] + \left[\frac{24{,}000}{12{,}000}(7{,}000)\right]$$

$$= 6{,}000 + 11{,}000 + 14{,}000 = 31{,}000$$

The trips from each district can then be calculated as follows:

District 1: $\frac{6{,}000}{31{,}000} \times 30{,}000 = 5{,}800$

District 2: $\frac{11{,}000}{31{,}000} \times 30{,}000 = 10{,}600$

District 3: $\frac{14{,}000}{31{,}000} \times 30{,}000 = 13{,}600$

Tech. Note 2:
Critical Accident Rate Factor

- Purpose

Traffic accidents are partially random and (fortunately) uncommon occurrences; consequently, calculated rates based on a few accidents are a volatile measure of safety conditions on a road segment or intersection. The critical rate method deals with this problem by using the traffic volume on which the rate is based to determine if the rate is significantly higher than average for the type of facility. Most states compile accident statistics by facility type, which may be determined by factors such as traffic volume, traffic control, access control, number of lanes, development density, and functional class.

The method is illustrated, in the following, using an urban arterial street segment that carries 15,400 vehicles per day. Over a 3-year period, 8 serious accidents (i.e., accidents resulting in death or injuries) and 15 other accidents have been reported along the 0.2-mile segment. The statewide average for similar facilities is 375 accidents per 100 million vehicle-miles, of which 120 are serious.

- Example Application

Step 1: Calculate Facility Accident Rate. The traffic volume on which a road segment accident rate is based usually is calculated in units of 100 million vehicle-miles (mvm), as follows:

$$TB = \frac{YRS \times AADT \times DIST \times 365 \text{ (days/year)}}{100 \text{ million}} \qquad (2\text{-}1)$$

where

TB = traffic base (100 mvm)

YRS = number of years of accident data used in calculating the rate

AADT = annualized average daily traffic

DIST = segment distance (miles)

The traffic base for the example segment is (3 x 15,400 x 0.2 x 365)/100 million = 0.0337. For an intersection, the traffic base would be calculated in millions of entering vehicles.

In calculating an accident rate for use as a performance measure, serious accidents often are given a higher weight than accidents that only result in property damage. The historical rate for a facility is calculated as:

$$AR = \frac{PDACC + (WT \times SACC)}{TB} \qquad (2\text{-}2)$$

where

AR = accident rate (per 100 mvm or per mev)

PDACC = number of reported property damage accidents

SACC = number of reported serious accidents

WT = weight applied to serious accidents

Alternatively, separate rates may be calculated for the different types of accidents and compared to a critical rate for each type.

Step 2: Calculate Critical Rate. The critical rate for a facility is calculated as:

$$CR = AVR + \frac{0.5}{TB} + TF \sqrt{\frac{AVR}{TB}} \qquad (2\text{-}3)$$

where

CR = critical rate (per 100 mvm or per mev)

TF = test factor

AVR = average accident rate for the type of facility

If weights have been used to calculate the facility's accident rate, the same weights must be applied to the average rate being used for comparison. In the example, the statewide average is calculated as 255 + (3 x 120) = 615 (equivalent) accidents per 100 million vehicle-miles.

The test factor establishes the severity of the statistical test on a facility's accident rate. A factor of 1.645, for example, is used if an agency wants to be 95 percent certain that the calculated accident rate indicates an unsafe condition; commonly used factors are given in the following table:

Confidence Level (%)	Test Factor
50	0.0
80	0.842
90	1.282
95	1.645
98	2.054

A 95 percent factor was applied in the example case, and a critical rate was calculated as 615 + (0.5/0.0337) + 1.645 $\sqrt{615/0.0337}$ = 852.

The ratio of the actual to critical rate of the facility measures the severity of the accident problem, with a ratio of 1.0 or higher flagging a likely problem for more detailed examination. The ratio for the example segment is 1160/852 = 1.4, indicating that a safety deficiency probably exists and that accident records should be examined to pinpoint specific causes.

- References

1. Homburger, W.S. (editor), Transportation and Traffic Engineering Handbook. Second Edition, Institute of Transportation Engineers, Prentice-Hall Inc., Englewood Cliff, N.J. (1982) 880 pp.

Tech. Note 3:
Speed-Volume Tables

- Purpose

There are many situations where it is desirable to quantify the travel time impacts of capacity changes along roadway segments. Examples are reversible lanes on a freeway or arterial street and contra-flow bus lanes.

Speed-flow relationships provide a means by which the effects of these changes can be estimated. These relationships can be used to estimate the changes in travel time resulting from expanding capacity, increasing vehicle occupancy, or reducing vehicle volumes.

The following tables present speed-volume relationships for freeways and arterial streets. The freeway table covers design speeds of 50, 60, and 70 mph; the arterial table covers initial or free-flow speeds ranging from 12 to 40 mph.

The values in the first columns are in equivalent passenger cars; an equivalency factor of 2.0 should be applied to trucks with 3 or more axles, and a factor of 1.6 should be applied to buses in using the tables.

A. Freeway[a]

Equivalent Passenger Cars per Lane per Hour	Volume/ Capacity Ratio[b]	Travel time (minutes per mile) when design speed is: 70 mph	60 mph	50 mph
800	0.40	1.13	1.20	1.30
900	0.45	1.13	1.21	1.33
1000	0.50	1.13	1.22	1.36
1100	0.55	1.13	1.23	1.39
1200	0.60	1.13	1.25	1.42
1300	0.65	1.14	1.29	1.46
1400	0.70	1.15	1.30	1.50
1500	0.75	1.18	1.33	1.58
1600	0.80	1.22	1.39	1.67
1700	0.85	1.26	1.46	1.76
1800	0.90	1.35	1.58	1.86
1900	0.95	1.50	1.71	2.00
2000	1.00	2.00	2.00	2.00

[a] Source: derived from Reference 1.

[b] Capacity at level-of-service E.

B. Arterial Street[a]

Volume/ Capacity Ratio[b]	Travel time (minutes per mile) when free-flow speed is: 40 mph	30 mph	20 mph	15 mph	12 mph
0.00	1.50	2.00	3.00	4.00	5.00
0.10	1.52	2.03	3.03	4.04	5.04
0.20	1.54	2.06	3.07	4.08	5.08
0.30	1.56	2.10	3.12	4.14	5.14
0.40	1.58	2.14	3.19	4.23	5.26
0.50	1.62	2.18	3.26	4.32	5.40
0.60	1.67	2.22	3.33	4.44	5.55
0.70	1.82	2.40	3.57	4.72	5.82
0.80	2.00	2.64	3.81	5.05	6.12
0.90	2.61	3.25	4.62	4.61	5.71
1.00	4.00	4.28	5.45	6.31	7.05

[a] Source: adapted from Reference 2, Figures 3-45, 3-46, and 10-3.

[b] Capacity at level-of-service E.

- Example Applications

1. An 8-lane urban freeway carries 7,200 vehicles in the heavy direction and 3,200 vehicles in the reverse direction during the peak-hour. A reverse flow operation is planned in which 6 lanes operate in the heavy direction and 2 in the off-peak direction. The savings in vehicle-delay can be determined as follows.

	------- Before -------	
	Heavy Dir.	Light Dir.
Vehicles	7200	3200
Lanes	4	4
Vehicles/Lane	1800	800
Min/Mile	1.35	1.13
Veh. Min.	9720	3620

	-------- After --------	
	Heavy Dir.	Light Dir.
Vehicles	7200	3200
Lanes	6	2
Vehicles/Lane	1200	1600
Min/Mile	1.13	1.22
Veh. Min.	8140	3900

Total vehicle-minutes (per mile) would decrease from 13,300 to 12,000, roughly a 10 percent saving.

3

2. An urban arterial street has a peak-hour one-way volume of 1,200. The street is 50 feet wide and is currently striped for 4 lanes. Operating speeds are 30 miles per hour and hourly capacity is estimated at 625 per lane. Restriping the street for five 10-foot lanes is planned with 3 lanes to be operated in the heavy direction. The savings in travel time can be determined as follows:

	Present	Proposed
Volume	1200	1200
Lanes	2	3
Capacity	1250	1875
V/C ratio	.96	.64
Min/mile	3.87	2.29
Veh.-Min.	4640	2750

The extra lane would reduce vehicle-minutes by approximately 40 percent.

- References

1. Transportation Research Board, "Interim Materials on Highway Capacity." Transportation Research Circular 212 (Jan. 1980) 272 pp.

2. Highway Research Board, "Highway Capacity Manual." Special Report 87, Washington, D.C. (1965) 397 pp.

Tech. Note 4: Transit Supply Estimation Procedure

- Purpose

A general procedure is presented for estimating: (1) the number of vehicles required to operate a transit route, and (2) other route supply measures commonly used for estimating operating costs. In cases where an existing route is being modified, direct measurements could be used instead of calculated values in some of the steps. Data collected on similar routes or route segments also could be used in estimating characteristics of new routes, allowing the detail of step 2 to be skipped. The general procedure as presented, however, provides a clear understanding of how many TSM actions might affect transit operating characteristics and supply.

The example used to illustrate the procedure is a new 3½-mile radial route planned as part of a corridor route restructuring. The route is expected to carry 650 passengers during the 90-minute morning commuting peak, with 450 of these passengers traveling inbound to the CBD.

- Example Application

Step 1: Set the Route's Service Frequency. Although extendable to the analysis of more complex operating plans, the procedure is presented for a single route where buses operate at a fixed headway (i.e., interval between buses, in minutes) during an operating or scheduling period (e.g., a.m. peak), and all buses travel the entire length of the route.

On many routes, the headway is set by policy; for example, a transit agency may operate all local radial routes at 15-minute (or shorter) headways during commuting peaks, at 30-minute headways during midday and early evening periods, and at 60-minute headways in the late evening. Crowding may occur, however, if higher volume routes are operated at policy headways. Those routes normally operate at a load-based headway, calculated as follows:

$$\text{HDWY} = \text{DURAT} \times \frac{\text{CAPY}}{\text{MAXLOD}} \qquad (4\text{-1a})$$

where

HDWY = operating headway (in minutes)

DURAT = duration of the operating or scheduling period (in minutes)

CAPY = bus operating capacity or the allowable passenger volume on a bus, on average, during the operating period; for an express route, this would probably be the number of seats, while for a local route, some standees would be acceptable during peak periods

MAXLOD = the total number of passengers crossing the peak load point in the peak flow direction during the operating period

Many agencies prefer operating with clock-face schedules, so the calculated headway might be rounded down to the nearest multiple of 5 or 10 minutes. This action, however, may increase the number of buses needed to operate the route.

The route would be operated at the smaller of the policy and load-based headway values. Service frequency (FREQ, in buses per hour) is simply the inverse of the assigned headway:

$$\text{FREQ} = \frac{60 \text{ (min/hr)}}{\text{HDWY}} \qquad (4\text{-1b})$$

In the example, a load-based headway for the AM peak would be calculated using the number of passengers entering the CBD and a bus operating capacity of 60, as follows:

$$\text{HDWY} = 90(60/450) = 12 \text{ min}$$

This value is less than the policy headway of 15 min, and, therefore, would be used as the operating headway during the morning peak. The service frequency would be 60/12 or 5 buses per hour.

Step 2: Calculate Segment Operating Times. Transit routes typically operate over segments that have different right-of-way, traffic, stop spacing and land-use characteristics. These factors all affect operating speed; thus, bus operating times are best estimated on a route segment basis, with each segment defined to have relatively uniform operating characteristics.

In the example, the route is divided into a 1½-mile segment on city streets near one- and two-family homes, a 1½-mile segment on city streets through higher residential density, and a ½-mile segment in the CBD. The inbound direction of the middle segment is used in the example calculations.

Segment operating time is best estimated as the sum of three components: (1) running time, including expected traffic delays; (2) passenger processing time, and (3) extra time at stops, including time for acceleration and deceleration. Average operating speeds (such as those presented at the end of this step) and direct time measurements, however, often can be used to obtain a good estimate. For an existing route, changes in selected components on some segments can be estimated using the equations that follow, and used to adjust measured operating times.

The first component, running time, is simply:

$$\text{RUNTIM} = \text{ADJFAC} \times \text{AUTOTM} \qquad (4\text{-}2)$$

where

RUNTIM = bus running time (in minutes)

AUTOTM = auto running time (in minutes)

ADJFAC = adjustment factor to account for the slower acceleration or cruising speed of buses

In many cases, a bus can keep up with traffic flow when not stopping to pick up or discharge passengers, and the adjustment would be set to 1.0. On a multi-lane artery with frequent traffic signals, however, a heavily loaded bus may be delayed by slow acceleration, and the factor may be as high as 1.2. Auto travel time would reflect traffic conditions during the operating period being analyzed. For buses operating on a separate right-of-way, travel time under free-flow conditions would be used instead of auto travel time. During peak periods, segment running times should be calculated separately for each direction of the route.

On the example segment, the auto travel time of 4.5 minutes (20 mph) is factored by 1.05, resulting in bus running time of 4.7 min.

Passenger processing time depends directly on the number of passengers boarded and discharged along the segment. The average passenger processing time on a single bus trip is calculated as follows:

$$\text{PAXTIM} = \frac{(\text{BOARD} \times \text{BRATE}) + (\text{ALIGHT} \times \text{ARATE})}{\text{FREQ} \times \text{DURAT}} \qquad (4\text{-}3)$$

where

PAXTIM = passenger processing time (in minutes)

BOARD = number of passengers boarding along the segment during the operating period

ALIGHT = number of passengers alighting along the segment during the operating period

BRATE = average boarding rate (in minutes)

ARATE = average alighting rate (in minutes)

Typical boarding/alighting rates, shown in the following table, can be used as guides in setting average rates for use in the equation.

Boarding/Alighting Characteristics	Average Time per Passenger (sec)
Boarding with simple fare	2-3
Boarding with zone fares or transfers	3-5
Single door alighting	2
Double door alighting	1½
Boarding/alighting with packages, strollers, canes, etc.	6
Wheelchair boarding/alighting	60+

In the example segment, boarding and alighting rates of 3 and 2 seconds, respectively, were used in estimating processing time, as follows:

$$\text{PAXTIM} = (340 \times 3 + 50 \times 2)/(5 \text{ X } 90) = 2.5 \text{ min}$$

Extra time spent at bus stops on a segment is calculated using the following relationship:

$$\text{XTRTIM} = \text{NSTOP} \times \text{PROBS} \times \frac{\text{TPSTOP}}{60} \qquad (4\text{-}4)$$

where

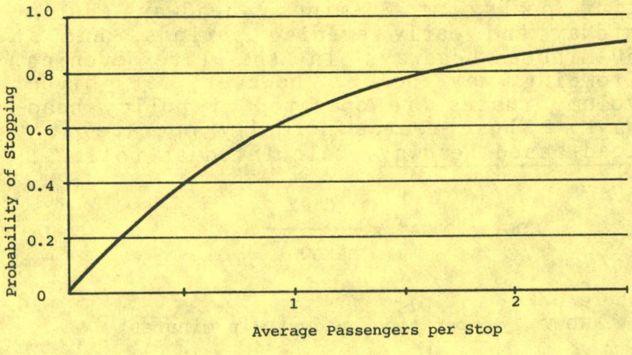
XTRTIM = extra time spent at bus stops (in minutes)

NSTOP = number of bus stops located along the segment

PROBS = probability of stopping

TPSTOP = average extra time per stop (in seconds)

The probability of stopping can be obtained from the following curve:



The average number of passengers per stop (PAXPS), used in the curve, is calculated as:

$$\text{PAXPS} = \frac{\text{BOARD} + \text{ALIGHT}}{\text{NSTOP} \times \text{FREQ} \times \text{DURAT}} \qquad (4\text{-}5)$$

There are 9 stops along the example segment, so the average value per stop per bus is (390/9)/(5 x 1.5) = 5.8 passengers, making the probability of stopping about 0.99.

The extra time per stop to allow for deceleration, acceleration, and opening and closing doors will vary with running speed. Assuming an acceleration rate of 3 mph per second, the extra time per stop (in seconds) will be as follows:

Running Speed (mph)	Extra time per stop (sec)
10	6-8
15	7-9
20	9-11
30	12-14
45	17-19

Merging into the traffic stream may require another 3 to 6 seconds. Another delay sometimes associated with stops is dropping out of a signal progression, which may add between 5 and 15 seconds per stop.

Approximately 12 seconds of extra time is needed for each stop along the example segment, so the total extra time along the segment is 9 x 0.99 x (15/60) = 1.8 minutes.

The segment operating time in the example (the sum of the three components) is 4.7 + 2.5 + 1.8 = 9.0 minutes, which represents an average operating speed of 60 x 1.5/9.0 = 10.0 mph. This speed appears reasonable for an inbound, radial route during the morning peak. The following table provides a rough guide for making similar assessments on estimates for other types of segments.

Type of Operation	Average Operating Speed (mph) Peak	Average Operating Speed (mph) Off-Peak
City local	5-15	8-20
Suburban local	10-25	15-30
Express with some freeway segments	15-30	20-40
Express on freeway	25-35	34-45

Average operating speeds for routes on local or arterial streets also can be obtained from the following table.

Stops per Mile	Average Operating Speed (mph) — Average Dwell Time per Stop — 10 sec.	15 sec.	20 sec.	30 sec.
1	30.5	29.3	28.2	26.1
2	25.0	23.4	22.0	19.5
3	21.0	19.4	17.9	15.6
4	18.3	16.6	15.3	13.0
5	16.0	14.4	13.1	11.1
6	14.0	12.5	11.3	9.5
7	12.8	11.4	10.3	8.6
8	11.3	10.0	9.0	7.5
9	10.0	8.9	8.0	6.7
10	8.6	7.7	6.9	5.8
12	7.3	6.5	6.4	5.3

Source: Reference 2, based on a 3-mph per sec acceleration and deceleration rates and on times observed in the field.

Step 3: Calculate Minimum Cycle Time. Cycle time is the time it takes a bus to travel the route in both directions and prepare to start a new run. In addition to round trip operating time, it includes any time required for driver breaks and slack time to allow for recovery from delays due to heavy traffic or high passenger volumes.

$$\mathrm{CYCTIM} = \mathrm{BRKTIM} + (1. + \mathrm{RFAC}) \times \sum_{j} \mathrm{OPTIM}_j \qquad (4\text{-}6)$$

where

CYCTIM = minimum cycle time (in minutes)

BRKTIM = time allowed for driver breaks at the end of a run (in minutes)

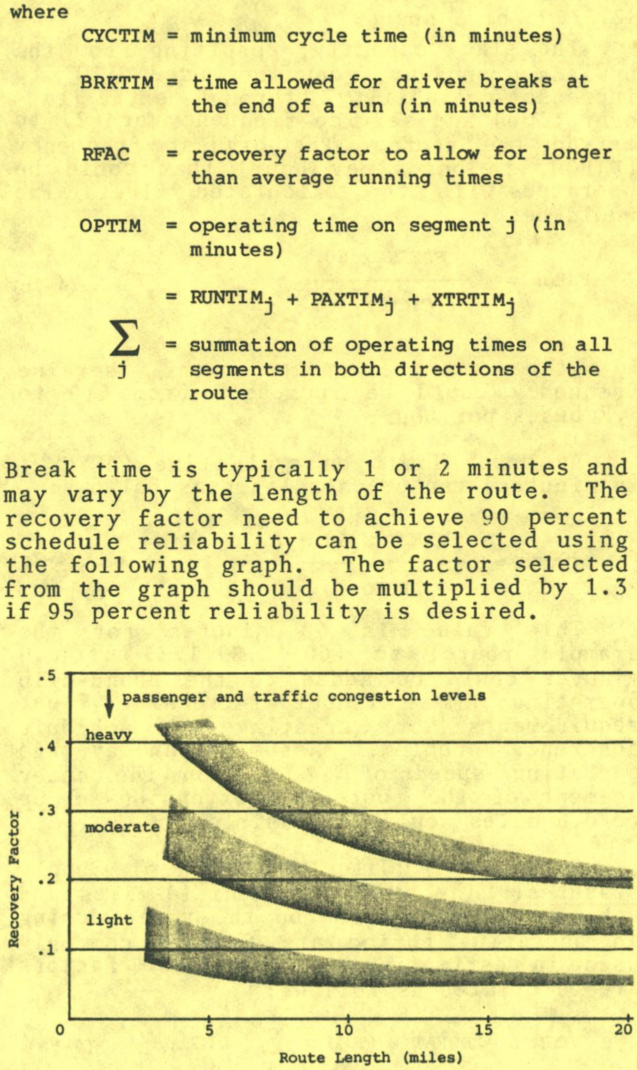
RFAC = recovery factor to allow for longer than average running times

OPTIM = operating time on segment j (in minutes)

$= \mathrm{RUNTIM}_j + \mathrm{PAXTIM}_j + \mathrm{XTRTIM}_j$

$\sum_j$ = summation of operating times on all segments in both directions of the route

Break time is typically 1 or 2 minutes and may vary by the length of the route. The recovery factor need to achieve 90 percent schedule reliability can be selected using the following graph. The factor selected from the graph should be multiplied by 1.3 if 95 percent reliability is desired.



The minimum cycle time estimated for the example route is 2 + (1. + 0.25) x 40.4 = 52.5 minutes.

Step 4: Calculate Fleet Required to Operate Route. The number of buses (FLEET) required to operate the route is calculated as:

$$\text{FLEET} = \left\lceil \frac{\text{FREQ} \times \text{CYCTIM}}{60.} \right\rceil \qquad (4\text{-}7a)$$

where the calculated value of the expression enclosed in brackets is rounded upwards to an integer.

The fleet required to operate the example route is calculated as 5 x 52.5/60 or 5 buses.

The slack capacity, resulting from the upwards rounding, can be used (1) to increase reliability (through extra layover time) and service frequency or (2) to extend the route. The highest frequency (FREQM, in buses per hour) that could be operated with the calculated fleet size would be:

$$\text{FREQM} = \frac{\text{FLEET} \times 60.}{\text{CYCTIM}} \qquad (4\text{-}7b)$$

In the example, route, the service frequency could be increased from 5.0 to 5.7 buses per hour.

An upper limit on cycle time (ACYCTM, in minutes) can be calculated as follows:

$$\text{ACYCTM} = \frac{\text{FLEET} \times 60.}{\text{FREQ}} \qquad (4\text{-}7c)$$

This value is 60 minutes for the example route, so (60-52.5)/1.25 or 6.0 minutes could be added to the round-trip operating time without increasing fleet requirements or creating a schedule adherence problem. Assuming an average operating speed of 12 mph on the outer segment of the route, an extension of up to 0.6 miles would be possible.

Step 5: Calculate Other Supply Measures. The number of vehicle-miles and vehicle-hours operated on the route during an operating period are factors commonly used in estimating costs. These factors are calculated as follows:

$$\text{VEHMIL} = \text{DURAT} \times \text{FREQ} \times \sum_j \text{DIST}_j \qquad (4\text{-}8a)$$

and

$$\text{VEHHRS} = \text{DURAT} \times \text{FLEET} \qquad (4\text{-}8b)$$

where

VEHMIL = vehicle-miles operated on the route

VEHHRS = vehicle-hours operated on the route

DIST_j = distance of segment j (in miles)

The example route uses 1.5 x 5 x 7 = 52.5 vehicle-miles and 1.5 x 5 = 7.5 vehicle-hours during the AM peak operating period.

- Additional Examples

To further demonstrate the procedure, assume the agency prefers clock face schedules and sets the headway at 10 minutes in step 1, yielding a frequency of 6 buses per hour. The only significant changes in operating time will be in passenger processing and the probability of stopping, because each bus trip processes only 5/6 of passengers carried in the base case. The time savings, approximately 2 minutes per bus trip, will not be sufficient to avoid an increase in fleet on the route; the route will require 6 x 50.5/60 or 6 buses.

The agency also might consider installing signal preemption hardware on major CBD and city arteries to improve reliability and reduce operating costs. The action might save about 2 minutes of extra time at stops on the inner two segments of the example route, plus reduce the schedule recovery factor to 0.20. If operated at 12-minute headways, the route would then require only 5 x 47.5/60 or 4 buses.

- References

1. Batchelder, J.H., et al., "A Systems Analysis of Transit/Paratransit Integration." Volume 2, Description of the Methodology. Prepared by Multisystems for USDOT/UMTA, contract DOT-UT-80007 (Oct. 1980) 150 pp.

2. Levinson, H.S., "Analyzing Transit Travel Time Performance." Paper presented at the Transportation Research Board Annual Meeting (Jan. 1983)

3. Levinson, H.S., Adams, C.L. and Hoey, W.F. , "Bus Use of Highways - Planning and Design Guidelines." NCHRP Report 155, Washington, D.C. (1975) 160 pp.

4. Gilbert, K., "Transportation Systems Management: Handbook of Manual Techniques for Transit Strategies." Prepared for North Central Texas Council of Governments (1977), distributed by USDOT/UMTA, Report No. TX-09-0045-81-1 (1981) 200 pp.

5. Levinson, H.S., "Bus Route and Schedule Planning Guidelines." NCHRP Synthesis of Highway Practice 69, Washington, D.C. (Mav 1980) 100 pp.

Tech. Note 5: Transit Service and Fare Elasticities

5

- <u>Purpose</u>

Transit service and fare changes may affect ridership and revenues, and elasticities derived from similar changes provide a quick means of estimating ridership changes. In general, the estimates will be reliable for planning purposes if the proposed fare or service levels are within 50 percent of existing conditions.

- <u>Example Application</u>

<u>Step 1: Select or Derive Elasticity</u>. Three forms of elasticity are reported in the literature, as follows:

<u>shrinkage ratio</u>:

$$E_m = \frac{M_b}{V_b} \times \frac{(V_a - V_b)}{(M_a - M_b)} \qquad (5\text{-}1a)$$

<u>logarithmic arc</u>:

$$E_m = \frac{\log (V_b) - \log V_a}{\log (M_b) - \log (M_a)} \qquad (5\text{-}1b)$$

<u>midpoint arc</u>:

$$E_m = \frac{(M_b + M_a)}{(V_b + V_a)} \times \frac{(V_a - V_b)}{(M_a - M_b)} \qquad (5\text{-}1c)$$

where

E_m = elasticity of ridership with respect to service measure m

V_b = ridership before the change

V_a = ridership after the change

M_b = service level or fare before the change

M_a = service level or fare after the change

The first of these forms, although simple to calculate and apply, produces values that are highly dependent on the "before" values and the direction of change. The second and third forms produce elasticities that are constant and presumably applicable over a greater range of conditions and changes; the values they produce are similar and can be used interchangeably. The use of the midpoint and logarithmic forms are strongly recommended for this and other reasons (see References 1 through 3).

Other researchers have compiled the effects of transit service and fare changes, and derived elasticities from these observations. Elasticities drawn from References 1 and 2 are given in the tables below to illustrate the range and variability of observed and estimated ridership responses. The elasticities are based on fare and service levels, and changes in these levels, observed during the 1960's and 1970's, and should not be used to estimate responses to conditions that will vary radically from conditions typical of those decades. Mayworm (4), for example, discusses evidence that fare elasticities will become increasingly negative as fare levels and the importance of fare in a traveller's overall impedance (i.e., a weighted sum of fare and various travel time components) increases.

TYPICAL SERVICE ELASTICITIES

Characteristic[a]	Elasticity[b]	# of Cases
<u>Vehicle-miles</u>		
Systemwide	+0.66 ± 0.26	6
Systemwide[c]	+0.78 ± 0.32	9
<u>Headway</u>		
Peak	-0.37 ± 0.19	3
Off-peak	-0.46 ± 0.26	9
Weekends	-0.38 ± 0.17	4
Less than 10 minutes	-0.22 ± 0.10	7
More than 50 minutes	-0.58 ± 0.19	10
<u>Total Travel Time</u>		
Peak	-1.03 ± 0.13	2
All hours	-0.92 ± 0.37	2
<u>In-vehicle Time</u>		
Peak	-0.29 ± 0.13	9
Off-peak	-0.83	1
Peak[c]	-0.68 ± 0.32	7
Non-work trip[c]	-0.12	1
<u>Out-of-Vehicle Time</u>		
All hours (bus and rapid rail)[c]	-0.59 ± 0.15	3
<u>Walk time</u>		
Peak[c]	-0.26	1
Off-peak[c]	-0.14	1
<u>Wait time</u>		
Peak (bus and rapid rail)[c]	-0.20 ± 0.07	4
Off-peak (bus and rapid rail)[c]	-0.21	1
<u>Transfer time</u>		
Peak (bus and rapid rail)[c]	-0.40 ± 0.18	3
<u>Number of transfers</u>		
Off-peak	-0.59	1

<u>Source</u>: References 1 and 2

[a] Bus only, unless otherwise noted.

[b] Mean value ± standard deviation, where available.

[c] Elasticities are based on nonexperimental data, e.g., data that do not reflect an actual fare change.

TYPICAL FARE ELASTICITIES

Characteristic [a]	Elasticity [b]	# of Cases
Fare		
Peak	-0.09 ± 0.04	4
Off-peak	-0.31 ± 0.16	8
All-hours [c]	-0.56 ± 0.28	14
Increase	-0.32 + 0.13	19
Decrease	-0.37 ± 0.11	9
CBD fare free zone	-0.52 ± 0.13	3
Senior citizen discounts	-0.27 ± 0.19	12

Source: References 1 and 2

[a] Bus only, unless otherwise noted.

[b] Mean value ± standard deviation, where available.

[c] Elasticities are based on nonexperimental data, e.g., data that do not reflect an actual fare change.

Step 2: Apply Elasticities to Estimate Ridership Changes. An elasticity is applied to estimate ridership using one of the following equations:

any change:

$$V_a = V_b \times \left[\frac{M_a}{M_b}\right]^{E_m} \qquad (5\text{-}2a)$$

small changes:

$$V_a = V_b \times \left\{1 + E_m \times \left[\frac{M_a}{M_b} - 1\right]\right\} \qquad (5\text{-}2b)$$

As an example, the operator of a small city bus company that operates 7.8 million bus-miles a year wants an estimate of the ridership increase that would result from a 10 percent increase in system operations. The company currently carries 9.4 million passengers annually. The average observed vehicle-mile elasticity in the table is 0.66, which yields an estimated ridership of 10.0 million riders using either equation. The operator also wants a conservative estimate of revenues, e.g., an estimate that will be exceeded 80 percent of the time. For this estimate, he reduces the mean elasticity by 0.842 times the elasticity's standard deviation (see Tech. Note # 2 for adjustment or test factors). This elasticity, equal to 0.66 - (0.842 x 0.26) or 0.44, yields an annual ridership estimate of 9.8 million.

- References

1. Mayworm, P.D., Lago, A.M. and McEnroe, J.M. Patronage Impacts of Changes in Transit Fares and Service. Prepared for USDOT/UMTA UPM-33 by Ecosometrics, Inc., Contract No. DOT-UT-90014 (Sept. 1980) 247 pp.

2. Barton-Aschman Assoc., Inc., Traveler Response to Transportation System Changes. Second Edition, prepared for USDOT/FHWA, Office of Highway Planning, Contract No. DOT-FH-11-9579 (July 1981) 400 pp.

3. Soberman, R.M. and Hazard, H.A. editors, Canadian Transit Handbook. University of Toronto and York University (Jan. 1980) 770 pp.

4. Mayworm, P.D., "Transit Fare Elasticity: Role in Fare Policy and Planning." Transportation Research Record 862, Washington, D.C. (1982) pp. 29-34.

Tech. Note 6: Inflation and Escalation Indices

- Purpose

Cost data for transportation operations and implemented actions often are not comparable because of regional and temporal differences in a dollar's purchasing power, and must be adjusted to a common base for use in assessing proposed TSM actions. Models for estimating costs, trip-making, mode choice, and user benefits also may not be reliable without adjusting their income or value-of-time coefficients to reflect current values. Indices that can be applied to make necessary adjustments are published regularly by the U.S. Department of Labor and other organizations; some of the more readily available and applicable indices are described below.

- Indices and Sources:

1. Consumer Price Indices for All Urban Consumers

Source: CPI Detailed Report
U.S. Department of Labor
Bureau of Labor Statistics
Washington, DC 20212

(or from regional offices in Boston, New York, Philadelphia, Atlanta, Chicago, Kansas City, Dallas and San Francisco)

Publication Frequency: Monthly

Geographic Categories: Indices are tabulated for (1) the nation, (2) selected major urban areas, (3) four city size classes, (4) four national regions, and (5) city size classes within each region.

Indices: Expenditures are separated into eight major categories: (1) food and beverages, (2) housing, (3) fuel and other utilities, (4) apparel and upkeep, (5) transportation, (6) medical care, (7) entertainment, and (8) other goods and services.

Indices are published for each category as well as for total expenditures. The categories also are broken down into line items; the transportation items include: (1) fuel, (2) maintenance and repairs, and (3) public transportation. A second categorization divides total expenditures into (1) commodities and (2) services, and the latter includes a transportation line item.

2. Producer Price Indices

Source: Producer Prices and Price Indices

U.S. Department of Labor
Bureau of Labor Statistics
Washington, DC 20212

Publication Frequency: Monthly

Geographic Categories: Nationwide

Indices: Producer price indices are provided for all standard commodity codes, and for specific products within most codes. Commodities of interest include:

- Gasoline (0571) - separate indices are provided for regular, premium and unleaded, and for sales of each to retail outlets and to commercial consumers.
- Diesel fuel (0573.03) - sales to commercial consumers only.
- Automotive oil (0576.01) - sales to retail outlets and to commercial customers.
- Tires (0712.01) - separate indices are provided for auto bias-ply, auto bias-belted, auto radial, and truck/bus tires.
- Motor vehicles (1411.01) - separate indices are provided for autos, light trucks, and heavy trucks.
- Motor vehicle parts (1412) - no breakdown.

Recent issues also contain regional prices and price indices for the various gasoline and diesel fuel codes.

3. Engineering News-Record Construction Cost Indices

Source: Engineering News-Record
McGraw-Hill Inc.
1221 Avenue of the Americas
New York, NY 10020

Publication Frequency: Weekly (city indices and indices based on 1967 published monthly).

Geographic Categories: Nationwide and for 22 large cities.

Indices: A composite construction cost index is provided, along with indices for materials, skill labor, and common labor components.

Tech. Note 7: Accident Reduction Factors

- Purpose

Low-cost roadway and traffic improvements often are designed to alleviate safety problems, but the effectiveness of these actions is difficult to estimate. State DOT's have conducted some before/after and other studies to obtain information on the effectiveness of different improvements, and these studies have been reviewed and compiled for the FHWA (1). Accident reduction factors reported for common TSM improvements are summarized below. Some are based on only a few observations, and in several cases the researchers noted large variations in accident reductions. More importantly, the reductions reported for different actions are based on their implementation in different settings to solve different types of accident problems. Consequently, the values should be used as rough indicators of potential effectiveness, and not as the sole basis for evaluating and comparing the effectiveness of specific improvements.

- Example Applications

1. Signal and channelization improvements are being considered for an intersection that averages 10 accidents a year. The factors in the table for "new signals with channelization" and similar actions indicate that a range of acccident reduction from 20 percent to 30 percent should be expected. While seemingly low, these factors include an expected increase in rear-end accidents that will partially offset a decrease in turn-related accidents. Other improvements that appear to be more effective in the table, such as raised barriers, are considered inappropriate for the (low) volumes and travel speeds and (balanced) traffic flows at the intersection being studied.

2. A conditions analysis has determined that turning movements from a high-speed multi-lane artery into side streets, and vice versa, are the primary source of a high accident rate (1.0 per million vehicle-miles) along the artery. A median barrier with left-turn bays is proposed as a solution. The table shows accident reduction factors of 65-70 percent for the improvement, which indicates an "after" rate of 1.0 x (1 - 0.65) or 0.35 accidents per million vehicle-miles. The statewide average for divided urban arteries, however, is 0.5 (per mvm), indicating a reduction of only 50 percent is more realistic.

APPROXIMATE ACCIDENT REDUCTION FACTORS

Improvement	Percent Accident Reduction	Source
• Traffic Signals		
- modified signals	6-10	2,4
- new signals	15-29	3,4
- new signals with channelization	20-27	4
• Channels (including left-turn bays)	32	2
• Left-Turn Channels at Signalized Intersection		
- left-turn phase	15-36	4
- no left-turn phase	15	4
- multi-lane urban	27	2
• Left Turn Channels at Unsignalized Intersection		
- curbs or raised bars	65-70	4
- painted channels	15-30	4
- 2-lane urban	19	2
- multi-lane urban	6	2
• 2-way Left-Turn Lane	10-30	5
• One-Way Streets	10-50	6
• Reversible Streets	up to 30	5
• Reversible Lanes	up to 10	5
• New Safety Lighting		
- at intersections	75[a]	4
- at underpasses	10[a]	4
• Pavement Grooving	75[b]	4

[a] Applies only to night accidents.

[b] Applies only to accidents on wet pavement.

References

1. McFarland, W.F., et al., Texas Transportation Institute, Assessment of Techniques for Cost-Effectiveness of Highway Accident Countermeasures. USDOT/FHWA Report No. FHWA-RD-79-53, College Station, Tex. (Jan. 1979) 350 pp.

2. Texas Department of Highways and Public Transportation, "Guide to the Highway Economic Evaluation Model." Austin, Tex. (Feb. 1976).

3. Fleischer, G.A., "Cost Effectiveness and Highway Safety." University of Southern California (1969).

4. Tamburn, T.N. and Smith, R.N., "The Safety Index, a Method of Evaluating and Rating Safety Benefits." Highway Research Record 352, Washington, D.C. (1970) pp.28-40.

5. Rowan, N.J., Woods, D.L. and Stover, V.G., Alternatives for Improving Urban Transportation - a Management Overview. Prepared for USDOT/FHWA by Texas Transportation Institute, Technology Sharing Report No. 77-215 (Oct. 1977) 100 pp.

6. Mayer, P.A., "One-Way Streets." Traffic Control and Roadway Elements - Their Relationship to Highway Safety, Highway Users Federation for Safety and Mobility (1971).

Tech. Note 8: Fuel Consumption Adjustment Factors

- Purpose

Many simplified techniques for estimating auto fuel consumption are based on the fuel efficiency of the auto fleet in the early or mid-1970's. Reductions in weight and improvements in vehicle and engine design have reduced energy consumption rates, and further reductions are expected. These reductions have not been uniform for all operating conditions; nonetheless, a simple factor can be applied to values obtained with simplified techniques to provide a rough estimate of a TSM action's likely effectiveness in reducing energy consumption. Adjustment factors developed in other NCHRP research (1) are shown below.

Analysis Year	Adjustment Factor	Analysis Year	Adjustment Factor
1975	1.000	1988	0.592
1976	0.980	1989	0.576
1977	0.955	1990	0.565
1978	0.931	1991	0.556
1979	0.902	1992	0.550
1980	0.871	1993	0.546
1981	0.831	1994	0.542
1982	0.791	1995	0.540
1983	0.747	1996	0.540
1984	0.748	1997	0.540
1985	0.670	1998	0.538
1986	0.638	1999	0.538
1987	0.612	2000	0.538

- Example Application

An analyst has applied one of the simplified fuel consumption estimation techniques in assessing a traffic signal and channelization improvement, and has estimated that the improvement will save 20,000 gallons of gasoline per year. That estimate, however, is based on 1975 operating conditions, and an average annual savings over the 5-year period of 1984-1988 is needed for the assessment. An average factor of 0.65 for those years is obtained from the table, and applied to revise the estimated annual savings to 13,000 gallons.

- References

1. Apostolos, J.A., et al., "Energy and Transportation Systems." NCHRP Project 20-7 (Dec. 1978)

2. New York State DOT Transportation Data and Analysis Section, "Energy Impacts of Transportation Systems Management Actions." Prepared for USDOT/UMTA, Report No. DOT-I-82-4, Albany N.Y. (Oct. 1981) 280 pp.

Tech. Note 9: Emission Rate Adjustments

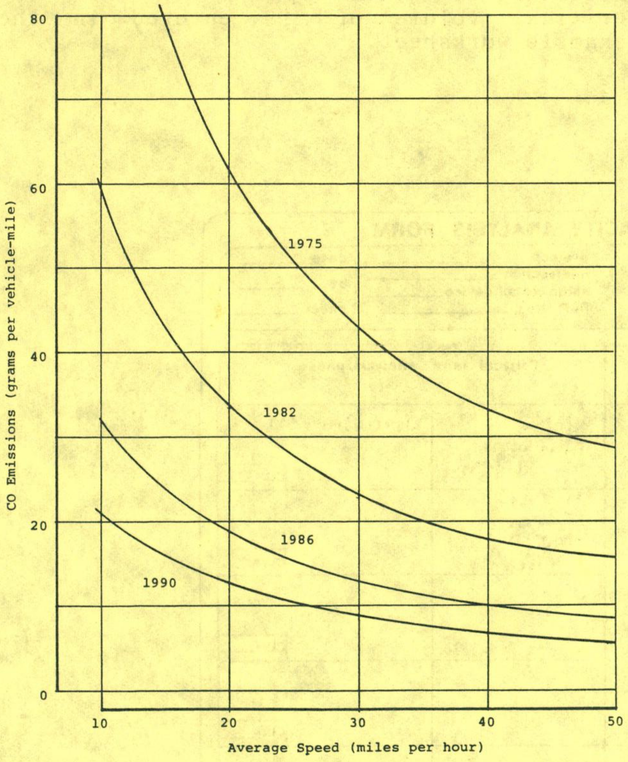
- Purpose

Many simplified techniques for estimating auto emissions are based on the fuel efficiency and emission control technology of autos on the road in the early or mid-1970's. Major reductions in emission rates have been achieved since then and will continue as the auto fleet is replaced. The FHWA has applied EPA's basic emission model, and produced tables of estimated average emission rates for autos and light trucks that quantify changes expected over the period from 1975 through 1999 (1). The tables provide rates for the following conditions:

- Operating speeds from 5 to 55 mph (in increments of 5 mph).
- Ambient temperatures of 0, 20, 40, 60 and 80°F.
- Cold start operation of 0, 10, 20, 30, 50 and 100 percent.

The following graph shows values of expected auto carbon monoxide emission rates (at 60°F and 10 percent cold start) extracted from the tables.

CARBON MONOXIDE EMISSION RATES (At 60°F, 10% cold start; source: reference 1.)



- Example Application

An agency has estimated that a signal coordination project will produce the 30 percent decrease in carbon monoxide emissions necessary to correct a hot spot along an urban artery. New office and apartment buildings, however, have been proposed for the corridor, and the agency has been asked to assess the impacts of these proposals.

The signal coordination design was based on 1982 traffic and air quality data. The artery carried 10,000 vehicles per day in that year. The emission rate tables indicate a carbon monoxide rate of 0.23 grams per vehicle-mile at 30 mph, the operating speed expected with the signal coordination in place, yielding CO emissions of 2.3 kilograms per mile per day.

The agency estimates that by 1986 the proposed development will increase traffic by 40 percent and degrade operating speed to 25 mph. The tables indicate a rate of 0.16 grams per vehicle-mile under those conditions, producing CO emissions of 2.2 kilograms per mile per day. In the near term, at least, a return of the air quality problem does not appear likely if the proposed development proceeds with the signal coordination project in place.

- References

1. USDOT/FHWA, "Mobile Source Emission Factor Tables." Technical Advisory Memorandum T6640-1 (Nov. 16, 1978) 140 pp.

Tech. Note 10:
Critical Lane Analysis

- Purpose

Critical lane (or critical movement) analysis is used to assess the service level of a signalized intersection. It is based on lane configurations and use, traffic signal phasing, and the volume of through and turning traffic. The critical volumes are the largest per lane volumes (of conflicting flows) during each signal phase. The sum of these values is then compared to intersection capacity to assess level-of-service.

Several variations of the technique are in use; some of these are described in the references provided at the end of this note. The variations reflect adjustments for factors such as (1) the maximum number of vehicles that can cross a point including effects of signal cycle length; (2) weightings for lane distributions, traffic composition, and turning traffic, and (3) treatment of left-turns. Two basic methods of critical lane analysis are presented below. The first examines the processing rate of the intersection itself, while the second looks at the flow capacity of the approaches.

- Example Applications

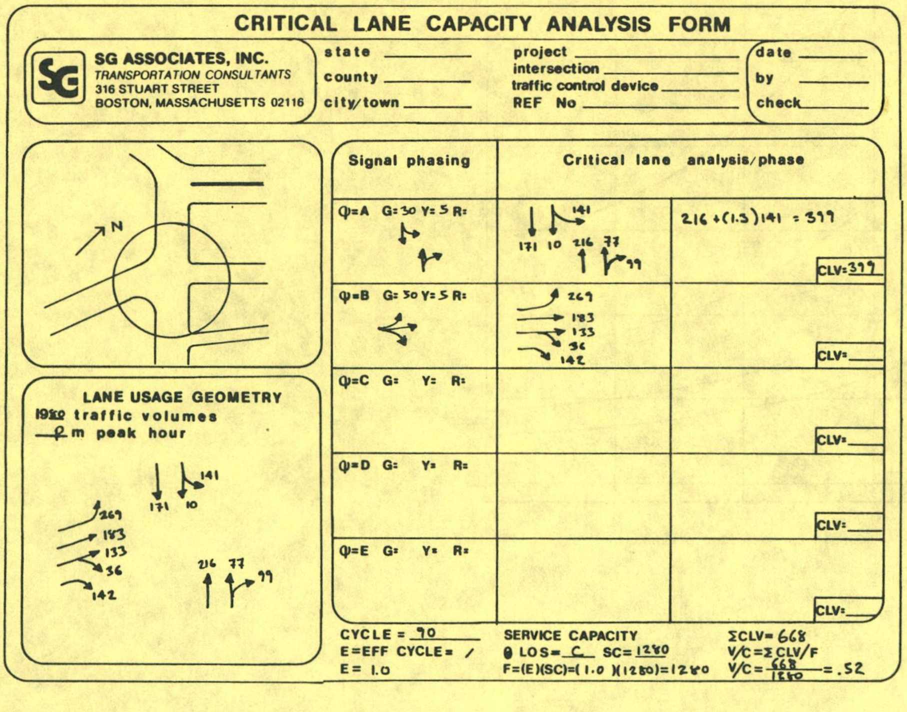
A. Processing Rate Method.

A simplified worksheet version of the intersection processing rate method is presented and illustrated using an intersection in downtown Boston; the worksheet for the example is shown below.

Step 1: Diagram lane usage. Hourly traffic volumes entering the intersection are distributed among lanes, with turning movements distinguished from through movements. Fifteen-minute volumes also could be used. The lane use diagram prepared for the example intersection is shown in the lower left corner of the worksheet; the volumes are afternoon peak-hour movements from counts taken in 1980.

Step 2: Analyze each signal phase. The right-hand side of the worksheet is used for analysis. Phase diagrams are entered in the first column along with the green and yellow times of each phase. The lane movements occurring in each phase are shown in the second column, transferred directly from the overall intersection diagram prepared in step one. The third column is used for calculating the critical lane volume. In phase B of the example, the critical lane volume is simply the highest lane volume, i.e., the 269 vehicles turning left. In phase A, southbound left turns cross oncoming traffic, so the sum of these flows must be considered. The turning traffic also must be weighted to account for interference between the opposing flows, for it crosses two lanes of traffic and a moderately used crosswalk. A weighting factor of 1.3 was selected from the graph shown on the following page, and applied to produce the critical volume of 399 entered in the example worksheet.

CRITICAL LANE WORKSHEET



CRITICAL LANE CAPACITY ANALYSIS FORM

SG ASSOCIATES, INC.
TRANSPORTATION CONSULTANTS
316 STUART STREET
BOSTON, MASSACHUSETTS 02116

state ______
county ______
city/town ______

project ______
intersection ______
traffic control device ______
REF No ______

date ______
by ______
check ______

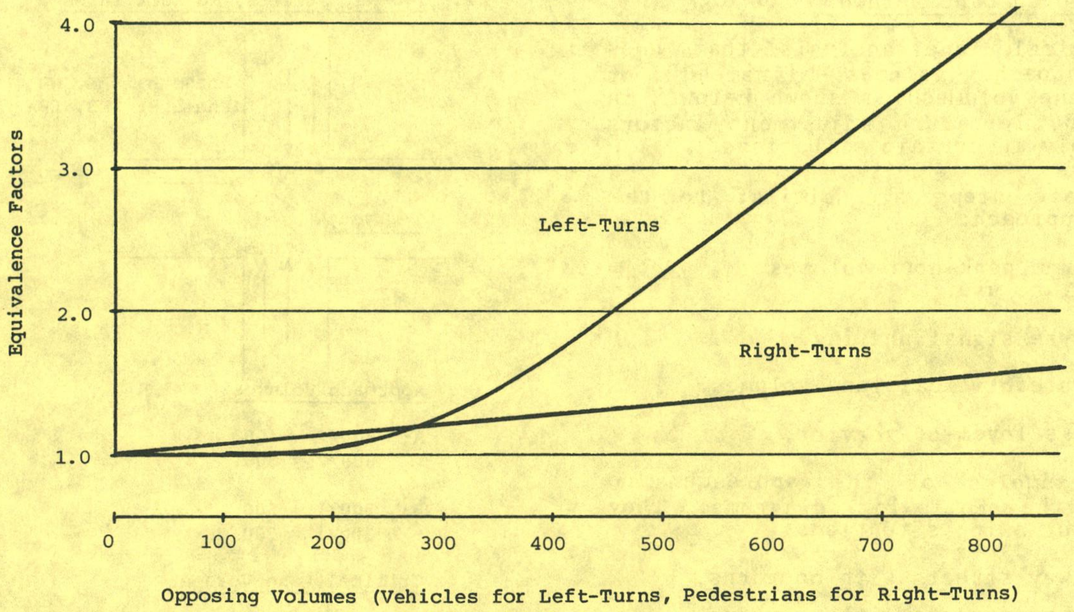
LANE USAGE GEOMETRY
1980 traffic volumes
p m peak hour

Signal phasing	Critical lane analysis/phase	
φ=A G:30 Y:5 R:	141 171 10 216 77 99	216+(1.3)141 = 399 CLV:399
φ=B G:30 Y:5 R:	269 183 133 36 142	CLV:___
φ=C G: Y: R:		CLV:___
φ=D G: Y: R:		CLV:___
φ=E G: Y: R:		CLV:___

CYCLE = 90
E=EFF CYCLE = /
E= 1.0

SERVICE CAPACITY
@ LOS= C SC= 1280
F=(E)(SC)=(1.0)(1280)=1280

ΣCLV= 668
V/C=ΣCLV/F
$V/C = \frac{668}{1280} = .52$



Source: derived from tables in Reference 2

<u>Step 3: Assess the intersection's capacity</u>. The space at the bottom of the worksheet is used to calculate a volume/capacity (V/C) ratio for the intersection. First, the effective cycle length is calculated as the sum of all green and yellow times; the ratio (E) of effective to total cycle time is used to account of the fraction of time the signals are all red or in an all-pedestrian phase.

Next, the service capacity (in vehicles per hour) corresponding to level-of-service E is read from the following table:

Cycle Length (sec)	---------Service Capacity-------- (corresponding to LOS-E)[a] 2 phase	3 phase	4 phase
50	1,440	1,260	1,080
55	1,470	1,310	1,150
60	1,500	1,350	1,200
65	1,520	1,380	1,250
70	1,540	1,410	1,290
80	1,580	1,460	1,350
90	1,600	1,500	1,400
100	1,620	1,530	1,440
120	1,650	1,570	1,500

The "maximum" capacity read from the table can then be adjusted to other levels-of-service, as follows:

A - 60%	C - 80%
B - 70%	D - 90%

In the example, the capacity for a 90-second, 2-phase cycle was adjusted to level-of-service C to produce a capacity estimate of (0.8 x 1,600) = 1,280 vehicles per hour. This value is then multiplied by the cycle ratio, E, to produce an effective service capacity, F. In the example, the ratio was 1.0, so no further adjustment was made.

Finally, the critical lane volumes are summed and divided by the effective capacity to produce a volume/capacity ratio corresponding to the desired level of service. In the example, the ratio is (399 + 269) / 1280 = 0.52, indicating that the intersection's capacity is sufficient to handle existing traffic at LOS C; a ratio greater than 1.0 would indicate a capacity deficiency.

---

[a] Based on 2-sec headways between cars and a 5-sec loss per phase.

B. Approach Lane Method.

A critical lane analysis that uses total approach volumes (instead of observed lane volumes) is shown below. In this method, left-turn adjustment factors are used only in certain situations.

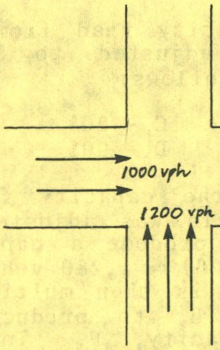
The basic steps are similar to the worksheet approach:

1. Diagram peak-hour volumes and lane use.
2. Analyze signal phasing.
3. Compute critical lane volumes.
4. Assess level-of-service.

Four examples of the approach are shown in the following diagrams; they cover the following situations:

1. One-way streets with no turns.
2. Two-way streets with no turns.
3. Two-way streets with potential left-turn lanes.
4. Two-way streets with single lane approaches.

1. One-Way Streets



Phase A: EB, WB
Phase B: NB, SB

Approach Volumes:

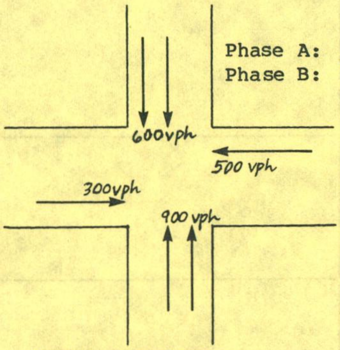
A: 1,000/2 = 500

B: 1,200/3 = 400

Critical Lane Volume:

A+B: 500 + 400 = 900

2. Two-Way Streets, No Left Turns



Phase A: EB, WB
Phase B: NB, SB

Approach Volumes:

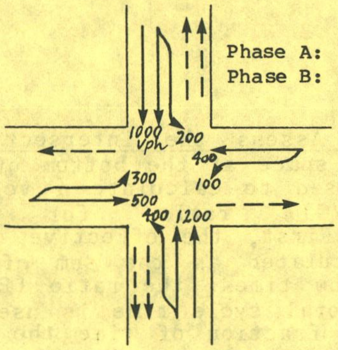
A: 900/2 = 450
600/2 = 300

B: 500/1 = 500
300/1 = 300

Critical Lane Volume:

A+B: 450 + 500 = 950

3. Protected Left-Turn Lanes



Phase A: EB, WB
Phase B: NB, SB

Approach Volumes:

A: 400/1 + 300 = 700
500/1 + 100 = 600

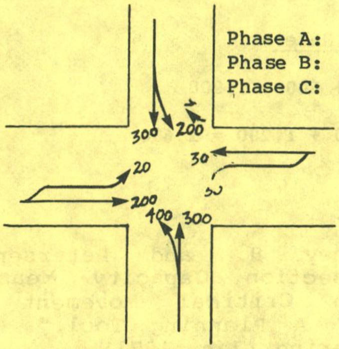
B: 1,200/2 + 200 = 800
1,000/2 + 400 = 900

Critical Lane Volume:

A+B: 700 + 900 = 1,600

Note: The analyses use flows that have been converted to passenger car-equivalents.

4. Shared Left-Turn Lanes (Single-Lane Approaches)



Phase A: EB, WB
Phase B: SB
Phase C: NB

Approach Volumes:

A: 200 + 50 = 250
300 + 20 = 320

B: 500

C: 700

Critical Lane Volume:

A+B+C: 320 + 500 + 700 = 1,520

The fifth example covers two-way, multi-lane streets without turn lanes. It is more complex, and requires the weighting factors presented with the worksheet approach. Step 3 (compute critical turn volumes) is expanded as follows:

3a. Obtain through-car equivalents for left turns.

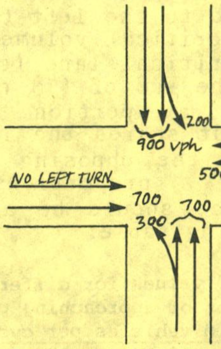
3b. Develop traffic flows in terms of through-car equivalents, and distribute equally by lane.

3c. Compute critical conflict volumes. (Note that the left-turns are added to the conflicting per-lane volumes resulting from step 3b.)

3d. Compute 'limiting case' volumes. This limiting case assumes that all N-S left turns preempt a lane and that through N-S traffic is limited to a single lane each way. This is the worst case, and it can never be exceeded by the value calculated in step 3c. Note that it gives a critical lane volume of 1,550 as compared to 1,250 in step 3c.

The example is diagrammed below.

5. Shared Left-Turn Lanes (Multi-Lane Approaches)



Phase A: EB, WB
Phase B: NB, SB

Approach Volume and Signal Phasing:

Left-Turn Adjustments:

B: 200 x 2.2 = 440
300 x 2.5 = 750

Approach Volumes:

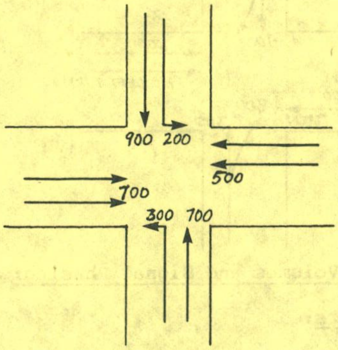
A: 700/2 = 350
500/2 = 250

B: (900 + 440)/2 + 300 = 970
(700 + 750)/2 + 200 = 925

Critical Lane Volume:

A+B: 350 + 970 = 1,320

Limiting Case (All left-turns in one lane, all through traffic in the other):



Critical Lane Volume:

A+B: 350 + 970 = 1,320

B: 900 + 300 = 1,200
700 + 200 = 900

A+B: 350 + 1,200 = 1,550

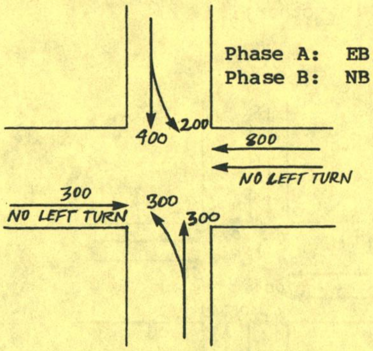
Example 6 gives a suggested approach for the treatment of left turns on a single lane approach. It is based on some ongoing research that adds a portion of the through-movement to the left-turn flow in determining the critical volumes. More specifically, the critical lane (conflict) volumes represent the sum of (1) the left-turn volumes, (2) a portion of the through-movement that shares the lane with left-turns, and (3) the opposing through-movement. The proportions of through-vehicles that should be added are given in the following table:

% of Traffic Turning Left	"K" values for different lengths of approaching platoons (in vehicles per cycle)			
	5	10	15	20
1	.03	.05	.08	.09
10	.25	.39	.50	.58
20	.39	.58	.69	.76
30	.53	.69	.78	.83
40	.61	.76	.83	.87
50	.67	.81	.87	.90
60	.72	.84	.89	.92

Source: Reference 4.

The derivation of a critical lane volume, using steps similar to example 5, is shown below.

6. **Shared Left-Turn Lanes (Single Lane Approach, No Special Phasing)**



Phase A: EB, WB
Phase B: NB, SB

Approach Volumes and Signal Phasing:

"K" Factors:

B(NB): 600 (veh/hr) 60 (cycles/hr) = 10 (veh/cycle)
50% left turns K = .81

B(SB): 600/60 = 10 (veh/cycle)
33% left turns K = .72

Approach Volumes:

A: 300/1 = 300
800/2 = 400

B: 300 + (.81 x 300) + 600 = 1,140
200 + (.72 x 400) + 600 = 1,090

Critical Lane Volume:

A+B: 400 + 1,140 = 1,540

Limiting Case:

B: 600 + 600 = 1,200

A+B: 400 + 1,200 = 1,600

- **References**

1. McInerney H. and Petersen, S., "Intersection Capacity Measurement through Critical Movement Summations: A Planning Tool." Traffic Engineering (Jan. 1971).

2. Transportation Research Board, "Interim Materials on Highway Capacity." Transportation Research Circular 212 (Jan. 1980) 272 pp.

3. Messer, C.J. and Fambro, D.B., "A New Critical Lane Analysis for Intersection Design." Paper for the 56th Annual Meeting of the TRB, Washington, D.C. (Jan. 1977).

4. Levinson, H.S., "The Effect of Left Turns on Intersection Capacity." Paper presented to the Highway Capacity Committee of the Transportation Research Board (Jan. 1982).

Tech. Note 11: Queue Length Analysis

11

- Purpose

In situations where intersections are closely spaced, a capacity analysis often is not a true indicator of system performance. The close proximity of the intersections coupled with the relatively high traffic volumes may create an interaction in which queues extend into or beyond upstream intersections, leading to increased delays and possibly to an interlock of the street grid or network often referred to as gridlock. Queue length analysis amplifies values derived using the critical lane method of capacity analysis, providing an estimate of queue lengths forming at each intersection approach. When plotted on a map, problem areas and conflicts are clearly illustrated.

The worksheet example presented in Tech. Note #10 (Critical Lane Analysis) is used to illustrate queue length analysis.

- Example Application

Step 1: Estimate Potential Queue Lengths. A conservative estimate of the length of the queue forming on each approach to a signalized intersection can be calculated using the following equation:

$$\text{queue length (ft)} = \frac{25 \times \left[\text{MRQ} + \text{TF} \times \sqrt{\text{MRQ}}\right]}{1 - \dfrac{\text{CLV}}{\text{CAP}}} \qquad (11\text{-}1)$$

where

MRQ = average queue forming during red phase $= \dfrac{\text{ALV} \times \text{R}}{3600}$

ALV = maximum approach lane volume (veh/hr weighted by critical lane factors)

R = red phase length on the approach (sec/cycle)

TF = test factor for desired confidence level (i.e., percent of time calculated queue length will not be exceeded) - see table in Tech. Note #2 for values.

CLV = critical lane volume of the intersection during green phase for the approach (veh/hr)

CAP = intersection capacity at level-of-service E (veh/hr)

The constants are an average storage requirement of 25 ft/veh and a conversion factor of 3,600 sec/hr. The use of critical lane weights in the ALV term reflects an effective increase in the red phase length for vehicles turning through opposing traffic flows, while their use in the CLV term reflects the reduced processing rate of the intersection. The denominator of the equation accounts for the possibility of queues not always clearing during green phases, while the TF term accounts for the variability in arrival rates.

In the example used to illustrate the critical lane method, the queues on the three approaches are estimated (at an 80 percent confidence level) as follows:

NW approach:

$$\text{MRQ} = \frac{(141 \times 1.3 + 10) \times 55}{3600} = 2.95 \text{ vehicles}$$

$$\text{queue} = \frac{25 \times \left[2.95 + .842 \times \sqrt{2.95}\right]}{1 - \dfrac{339}{1500}} = 142 \text{ ft}$$

SW approach:

$$\text{MRQ} = \frac{269 \times 35}{3600} = 2.62 \text{ vehicles}$$

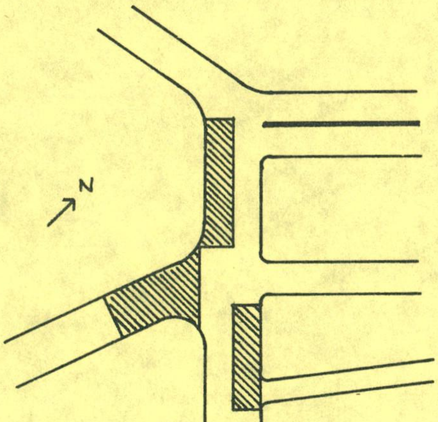
$$\text{queue} = \frac{25 \times \left[2.62 + .842 \times \sqrt{2.62}\right]}{1 - \dfrac{269}{1500}} = 121 \text{ ft}$$

SE approach:

$$\text{MRQ} = \frac{216 \times 55}{3600} = 3.30 \text{ vehicles}$$

$$\text{queue} = \frac{25 \times \left[3.30 + .842 \times \sqrt{3.30}\right]}{1 - \dfrac{339}{1500}} = 156 \text{ ft}$$

Step 2: Plot Queue Lengths. When plotted on an intersection diagram, shown below, the queues formed on the NW and SW approaches in the example clearly have the potential to interfere with upstream intersections. While an interference problem may not currently exist, the method shows that the operation of intersections in the immediate vicinity must be carefully coordinated to avoid a problem.



peak-hour queue lengths exceeded only 20% of the time

11

- References

1. Unpublished memoranda; the method is used by Maine DOT and has been validated and applied in downtown traffic studies in Boston and Baltimore.
2. Patterson, R.M., "Air Quality Modeling at Signalized Intersections." Workshop paper in Transportation Research Board Special Report 167, Washington, D.C. (1976) pp. 138-141.

NOTES

Additional Planning and Evaluation Aids

This section contains additional information to assist agencies in planning and programming TSM actions. Notes on Evaluation and Packaging Techniques discuss various techniques that, although not recommended for general application, might prove useful in certain aspects of some agencies' strategic management or project planning activities. A short directory of TSM Information Sources also is provided; it contains a basic reference library for planners in smaller communities and a list of agency offices that distribute information on TSM actions or simplified analysis and evaluation techniques.

Notes On Evaluation and Packaging Techniques

The research that led to this manual included a review of several problem assessment, project packaging, and priority setting techniques. Although none of those reviewed could be recommended for rigorous application in evaluating TSM actions or in developing TSM programs, several might prove useful to some agencies in performing aspects of their strategic management or project planning. Consequently, the following notes from the review are included in this handbook:

1. Problem Assessment Techniques
2. Project Packaging Techniques
3. Benefit/Cost and Cost/Effectiveness Analysis
4. Program Development Techniques

E/P Note 1: Problem Assessment Techniques

- Description

Over the past 30 years, many transportation agencies have developed or adopted procedures that systematically assess the condition of their facilities and services and identify those in need of correction or improvement. These procedures are generally called sufficiency, deficiency, or performance ratings, and are applied either as part of special studies or in conjunction with periodic or ongoing reviews such as highway inventories, need studies, and transit route performance evaluations. Recent publications by the Transportation Research Board (1, 2, 3) discuss these procedures and provide references to examples of their development and application.

Streets and highways typically are rated using a variety of factors for which national, state, or local design or performance standards have been set. The following types of factors are in common use:

- Geometric and alignment characteristics (e.g., pavement width, lane width, and horizontal and vertical curvature).
- Physical condition (e.g., damage and wear on structures, roadbed, pavement, and curbs).
- Signing (e.g., signal and sign design and placement, and striping design and condition).
- Safety (e.g., accidents and accident rates, warning devices, and guardrails or other protection).
- Service quality (e.g., operating speeds, delays, and volume/capacity ratios).

Most of these factors are assessed using simple, three- to ten-value (numeric or verbal) scales defined in manuals or instruction books, with a city, county, or state engineer entering the ratings on a field inventory form. Others, such as volume/capacity ratios, are derived from field data using simple procedures or worksheets, or calculated by computerized inventory processing programs.

The ratings may be used separately, but most often are combined using weights to obtain categorical or overall adequacy ratings. Georgia (4), for example, calculates combined physical, operational (i.e., geometrics, service, and traffic volume) and safety deficiency ratings for all facilities, while AASHTO (5) has developed composite (1) structural adequacy and safety and (2) serviceability and functional obsolescence ratings for assessing bridges. Thiers, Hoel, and Detorre (6) used geometric and physical condition factors to develop component ratings for "cartways," curbs, and sidewalks in an assessment of urban streets, then weighted the component measures to produce a combined rating for each street. The components and weights used in the Georgia ratings are shown below as an example of this approach.

GEORGIA DEFICIENCY RATINGS

Ratings and Component Factors	Weight
Physical deficiency	
Structural condition	.25
Structural adequacy	.25
Pavement condition	.25
Pavement adequacy	.25
Operational deficiency	
Traffic volume	.28
Volume/capacity ratio	.22
Speed and delay	.30
Roadway alignment and geometric	.20
Safety deficiency	
Accident experience	.34
Accident potential	.34
Roadway alignment and geometric	.32

Source: (1)

Other types of factors have been developed and included in categorical or overall adequacy ratings when those ratings have been used to methodically rank or assign priorities to problems. These factors can be categorized as:

- Network importance (e.g., functional classification, traffic volumes, service and geometric comparisons with connecting and alternate roads, and use by emergency vehicles, heavy trucks, or school buses).
- Institutional or community (e.g., source of problem identification or request for action, and number of complaints).

The Georgia formula (4), for example, uses both categories, and the AASHTO bridge sufficiency rating (5) includes an "essentiality for public use" component.

Categorical or overall ratings can be useful, because they summarize detailed measures and help officials digest and compare reports for scores or hundreds of facilities. The process of aggregation, however, obscures information that may be valuable in making good decisions. In a test of urban street ratings in Phoenix, for example, Hall and Hixon (7) examined differences between professional judgment and formula ratings incorporating geometric, physical condition, safety and service quality factors. In many of these cases, a committed or recently completed improvement on a parallel facility was the reason for the assignment of a lower priority by agency officials, because they viewed the problem as partially or fully resolved. Another situation producing large rating differences was the existence of a severe safety or structural deficiency on an otherwise adequate facility. The professional engineers generally would assign a higher priority to that situation than the formula rating, where the weights effectively hid the problem.

Weighting schemes have other problems. A consistent set of components and weights are hard to develop, for many deficiency factors are related and thus difficult to separate. In the Georgia ratings, for example, volume/capacity and speed/delay factors both are used in developing an operational deficiency rating, even though they essentially are different measures of the same problem. The weights also are hard to publicly defend, and tend to become obsolete as the public's priorities change. For example, physical condition and safety factors would increase in importance in a period of fiscal austerity, while service quality factors would decrease. These limitations are particularly acute in short-range planning where problems are immediate and readily observable by the public, and can assume an importance quite different from their professional assessment.

Similar factors have been developed by transit operators (and other agencies) to assess the performance of individual transit routes against regional or state standards or warrants; the factors most commonly used measure:

- Productivity (of drivers or vehicles, e.g., passenger-miles or passengers boarded per vehicle-mile, per vehicle-hour or per driver-hour).
- Service quality (e.g., percentage of vehicle trips dispatched on schedule, percentage of trips arriving on schedule, percentage of passenger-miles spent standing, and peak and base frequency).
- Cost recovery (e.g., percentage of operating costs covered by farebox revenues).

San Diego Transit (8), for example, uses the following three measures to evaluate routes in each operating period (e.g., a.m. peak):

- Passengers per bus hour.
- Operating ratio (i.e., revenues per dollar of operating costs).
- Maximum load factors (i.e., passengers per seat at the peak directional load point).

These measures can be used individually to identify problem routes, or can be combined to provide an overall measure of a route's adequacy. Adding productivity and cost-recovery factors, however, verges on double counting, for these measures are highly correlated.

Equivalent measures also are used to assess system-wide performance, with total employees and vehicles also used as the denominators of productivity measures. Additional measures, such as coverage (e.g., percentage of area residents living within a half-mile of bus routes or arterial highways) and average speed also are used to assess system-wide service quality. A report by Attanucci and others (9) tabulates the performance measures used by 71 transit operators, as well as the data collection procedures and evaluation criteria used in developing and applying the measures. Wilson and Gonzalez (10) describe the use of performance measures in identifying opportunities for improved service quality and efficiency, as well as to identify problems.

- References

1. Transportation Research Board, "Priority Programming and Project Selection." NCHRP Synthesis of Highway Practice 48, Washington, D.C. (1978) 31 pp.
2. Transportation Research Board, "Bibliography on Project Evaluation and Priority Programming Criteria." Transportation Research Circular 213, Washington, D.C. (Jan. 1980) 35 pp.
3. Transportation Research Board, "Transportation Needs Studies and Financial Constraints." NCHRP Synthesis of Highway Practice 72, Washington, D.C. (Oct. 1980) 54 pp.
4. Federal Highway Administration, "Seven Approaches to Highway Programming." Draft Report 4 of Statewide Transportation Planning and Management Series, Washington, D.C. (June 1981) 80 pp.
5. AASHTO, "Summary of Sufficiency Rating Factors" (March 1976).
6. Thiers, G.R., Hoel, L.A., and Detorre, J.N., "Developing Priorities for Street Improvement Programs in Urban Areas." Highway Research Record 348, Washington, D.C. (1971) pp. 109-118.

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7. Hall, E.M. and Hixon, C.D., "The Use of a Priority Formula in Urban Street Programming." Highway Research Record 87, Washington, D.C. (1965) pp. 57-72.

8. San Diego Transit, "Five Year Plan Update, FY 1981-1985." San Diego, Calif. (July 1980) 300 pp.

9. Attanucci, J.P., Jaeger, L., Becker, J., Bus Service Evaluation Procedures: A Review. Report prepared for USDOT/UMTA, UPM-13, Report No. UMTA-MA-09-7001-79-1, NTIS No. PB79-296314 (April 1979) 220 pp.

10. Wilson, N.H.M., and Gonzalez, S.L., "Methods for Service Design." Transportation Research Record 862, Washington, D.C. (1982) pp. 1-8.

E/P Note 2:
Project Packaging Techniques

- Description

The packaging of TSM actions is an integral part of several strategic management and project planning activities, starting with problem assessment and project scoping and ending with the recommendation and scheduling of (staged) implementation. All four project planning phases described in Chapter Three may involve packaging decisions. The literature related to packaging covers some but not all of these activities.

Remak and Rosenbloom (1) have identified some conceptual packages of TSM actions for reducing congestion in central business districts and other areas; these would be useful in identifying candidate actions for possible inclusion in initial design options. The Action Identification Tables expand on this and similar efforts, and identify the actions that might be packaged as part of (alternative) initial solutions for several typical problems.

Case studies of corridor and subarea packaging have been published that illustrate the candidate projects, the final recommendation, and some of the procedures used in developing the packages. Procedures described in these studies range from professional judgment to network simulation.

Corridor studies in Portland (2) and Dayton (3) provide examples of the successful application of professional judgment to package projects in corridors and subareas. In both cases, interagency task forces worked together to assemble mutually supportive projects that were in scale with identified problems and available resources. Performance and cost estimates prepared for individual projects were used in developing the packages, but no attempt was made to quantify any synergistic effects. The Portland study also illustrates the grouping of problems into corridors and subareas for common resolution.

Analytical techniques such as cost-effectiveness and benefit-cost analysis could be applied to help package TSM actions by examining the incremental contribution of individual actions to the effectiveness of the overall package. While no examples of their rigorous use have been identified, techniques using their principles have been developed and applied. In a study of TSM actions to encourage the development of Santa Barbara's CBD while avoiding increased traffic, Larwin and Stuart (4) rated each proposed action against 13 objectives using a scale of 1 to 5 and used the resulting objective-achievement matrix as a basis for preparing a recommended plan. A more quantitative approach was used by the North Central Texas Council of Governments (NCTCOG) in an analysis of highway geometric and signalization improvements in a suburb between Dallas and Ft. Worth (5). A network-based model was used to identify travel deficiencies in directional movements through the subarea, and to analyze the effectiveness of alternative actions in reducing travel times. In preparing an energy contingency plan for greater Cleveland, Voorhees (6) used calculated estimates of the energy savings of individual actions to develop packages designed to produce different levels of regional energy reduction.

In all these examples, a consistent evaluation using quantitative and qualitative factors was applied with a knowledge of the problem setting to produce logical combinations of actions. The packaging process, however, is presented almost as a small-scale programming of individual intersection, road-segment transit route and other actions. What is lacking is a clear presentation of coordinated design decisions made to solve related problems.

On a small scale, design coordination is obvious to most agencies. The combination of (1) park/ride lots and express bus routes, or (2) parking restrictions near intersections with new turn lanes are examples. Less obvious are some larger packages that have been given names such as transit malls and auto-restricted zones (ARZ's) and treated as single actions in the literature. The Boston ARZ is a good example of a coordinated package of parking restrictions, pedestrian-only streets, intersection realignments and signalization changes, revised one-way street patterns, and bus route modifications carefully designed using an iterative process to meet a variety of site-specific objectives (7).

- References

1. Remak, R. and Rosenbloom, S., "Implementing Packages of Congestion-Reducing Techniques, Strategies for Dealing with Institutional Problems of Cooperative Programs." NCHRP Report 205 (June 1979) 128 pp.

2. Metropolitan Service District, Transportation System Management Prototype Planning Study: Portland. Report No. UMTA-IT-09-0068-79-1, Portland, Oregon (Nov. 1979) 114 pp.

3. Montgomery - Greene County Transportation Coordinating Committee, "1980 Transportation System Management Report." Dayton, Ohio (1980) 120 pp.

4. Larwin, T.F. and Stuart, D.G., "Transportation Management Strategies: Prospects for Small Cities." Transportation Research Record 603, Washington, D.C. (1976) pp. 49-56.

5. Howe, S.M., Ryden, T.K. and Penny, D., "Subarea Diagnostic and Evaluative

Procedures for Programming Short-Range Transportation Improvements." Transportation Research Record 648, Washington, D.C. (1979) pp. 9-15.

6. Alan M. Voorhees and Assoc., "Alternative Forecasts for identified Energy Implementations in Northeast Ohio." Report prepared for the Northeast Ohio Areawide Coordinating Agency, McLean, Va. (Dec. 1975) 100 pp.

7. Weisbrod, G., "Business and Travel Impacts of Boston's Downtown Crossing Automobile-Restricted Zone." Transportation Research Record 882, Washington, D.C. (1982) pp 25-32.

E/P Note 3: Cost-Effectiveness and Benefit/Cost Analysis

- Description

Cost-effectiveness and benefit/cost analysis are techniques for making quantitative comparisons among projects. They can be applied in project planning to compare and evaluate alternative designs, or in program development to allocate funds among projects at different sites. The key features, strengths, and weaknesses of these techniques are discussed below.

Cost/effectiveness analysis uses ratios of individual effectiveness or performance measures to costs to evaluate and compare projects; examples are accidents eliminated per dollar invested and hours of delay saved per dollar invested. Its strength is that it can be used with any evaluation and performance measures that can be quantified and presented in a form where higher values or scores connote better investments. Its weakness is that different factors cannot be combined; separate comparisons must be made for each measure of interest, rather than a single comparison that takes all important measures into account.

Benefit/cost analysis provides the means of combining and weighing different types of measures through the assignment of monetary values (e.g., value of time savings and value of avoiding an injury). It also deals with the diverse timing of the various costs and "benefits" through the use of a discount rate, which is used to convert all future values of costs and benefits to comparable "present values." (A discount rate is essentially equivalent to an interest rate, but measures the relative social importance of current versus future benefits as well as the time value of money.) Summary measures produced from these present values are the primary evaluation measures used in a benefit/cost analysis. The net present value, the arithmetic difference between present values of total benefits and capital costs, measures the net benefit to the public of implementing a project alternative. The benefit/cost ratio, the quotient of the present values of total benefits and capital costs, measures the rate (i.e., benefits per dollar invested) at which benefits accrue. The measures are useful both in the analysis of alternative improvements at individual sites and in the development of investment programs.

The weakness of benefit/cost analysis is that it is limited to measures to which dollar values can be assigned; these typically include user time and cost savings, accident reductions, changes in maintenance and operating costs, and implementation costs. Consequently, benefit/cost often must be supplemented by assessments of nonquantifiable measures. In addition, analyses using different sets of monetary factors (such as discount rates and values of lives saved) often are necessary because a consensus on their values is difficult to reach. In using benefit/cost analysis to help prepare a 6-year highway program, for example, the Wisconsin DOT developed candidate programs that emphasized different objectives (e.g., safety improvements vs. travel time savings) and used consistency of inclusion in these candidate programs as a criteria for selecting projects (2).

The use of benefit/cost analysis in project planning and program development is illustrated below. Most of the discussion of these examples also would apply to cost-effectiveness analysis; the major exceptions are that no significance can be attached to a ratio being greater than or less than one, and there is no equivalent to "net present value."

- Project Planning Application

Six alternative packages for improving capacity and traffic flow along an arterial corridor have been developed, and are being evaluated as part of Phase 3 of project planning. The performance of each alternative has been estimated using current traffic volumes, and using volumes forecast in 10 years. Aggregate benefits have been calculated for each by comparing their performance with the continued operation of unimproved streets and applying the following factors to the estimated differences:

- $4.00 per hour saved by auto drivers and passengers.
- $10.00 per hour saved by commercial vehicles.
- $30,000 per reduced serious accident.
- $800 per reduced minor accident.
- $1.00 per gallon of fuel saved.

Reductions in facilty operating and maintenance costs also were included in the benefit measure, with an increase in these costs considered as a negative benefit. A discount rate of 7 percent (exclusive of inflation) was applied to convert future benefits to present values.

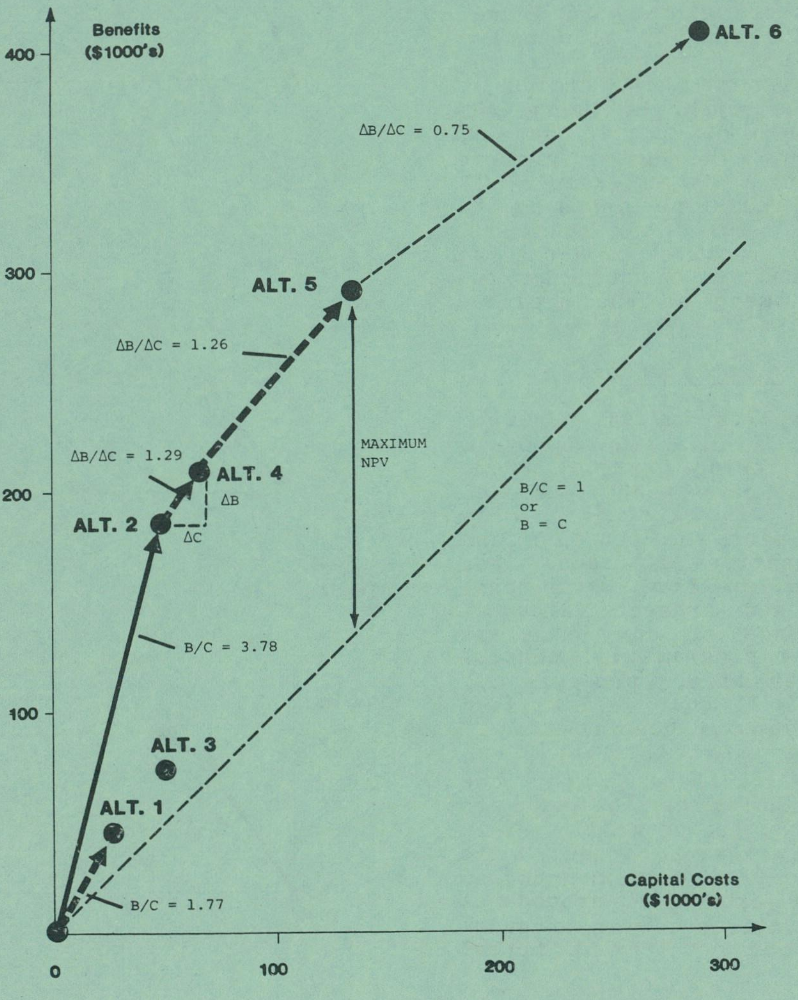
The benefits calculated for the alternatives can be plotted against their capital costs, as shown in the graph below. The graph also displays the other major economic measures calculated for each alternative. The benefit/cost ratio of each alternative is the slope of the line connecting the origin (which represents the "no-build") and the dot depicting the benefits and costs of the alternative; the net present value is the vertical distance between the alternative's dot and the dashed line labelled B/C=1 (which shows where benefits equal costs).

All six alternatives meet the primary test of a benefit/cost analysis, i.e., their benefits exceed their costs. Other ways of expressing this test are "a benefit/cost ratio greater than 1.0" and "a positive net present value."

The comparison of alternatives and the recommendation of a few to consider during priority programming require a more detailed examination of benefits and costs. This is most easily done in an iterative procedure in which funds are successively "committed" to the study area or project site as long as (1) at least a dollar in benefits is derived from each dollar invested and (2) funds are available to make the investment. In each pass through the procedure, the objective, from an economic perspective, is to achieve greatest benefit from each dollar invested.

The procedure starts with the no-build, which cost nothing and yields no benefits. The highest return attainable at the site, as shown in the graph on the preceding page, is the implementation of Alternative 2, which returns benefits at the rate of nearly 4:1. Alternative 1, which yields benefits at less than half this rate, would be discarded unless an agency expected that the funds required to implement Alternative 2 would not be available. If funding beyond the cost of Alternative 2 is expected, the procedure continues as long as additional investment is worthwhile. In the example, the additional cost of constructing Alternative 4 instead of Alternative 2 is $230,000. This investment will produce an additional $300,000 in benefits, which accrue at the rate of $1.29 for each dollar invested beyond the $490,000 needed to construct Alternative 2. This incremental benefit/cost ratio of 1.29, not the total ratio of 3.0, indicates that Alternative 4 is a good investment. Similarly, an incremental benefit/cost ratio of 1.26 can be calculated for the additional investment

COMPARISON OF ALTERNATIVE PACKAGES



necessary to implement Alternative 5, indicating that funds beyond the $720,000 required for Alternative 4 can be beneficially invested at the site.

Additional investments beyond the amount needed to build Alternative 5, however, do not produce sufficient additional benefits to cover the additional costs. Therefore, Alternative 6 is not a good investment, in spite of its total benefit/cost ratio of 1.9. (Note that if Alternative 6 was analyzed in isolation, i.e., with no consideration given to the lower-cost alternatives, it would have appeared to be a worthwhile investment. Thus, the examination of a range of alternatives is essential to a sound benefit/cost analysis.)

In summary, every dollar invested up to the $1.34 million necessary to build Alternative 5 increases the difference between total benefits and total costs (i.e., the net present value) at the site. Beyond $1.34 million, the net present value declines. In the absence of any budgetary constraints, the best alternative to implement is the one which produces the highest net present value.

If there are funding limitations, the best investment at a site will depend on the costs, net present values, and incremental benefit/cost ratios of alternative projects at all sites competing for the limited funds. In general, the choice at the application site would be among the no-build and Alternatives 2, 4, and 5, because the others produce inferior returns on investment. As an example, if all program funds could be invested to produce benefits at rates of at least 3:1 as a result of attractive projects at other sites, Alternative 2 would be the alternative to implement at the application site.

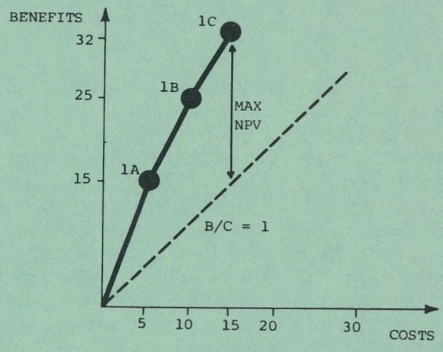
- Program Development Application

A simplified application of benefit/cost in developing an investment program is shown in the following example, where alternative packages have been developed in four corridor and subarea studies. The graphs shown below plot the benefits and costs of the alternatives at each site, and indicate the alternative which produces the maximum net present value at each. In the absence of any budgetary constraints, the best program will consist of these alternatives (i.e., projects 1C, 2B, 3, and 4A); it will cost $4.5 million and produce $7.9 million in benefits.

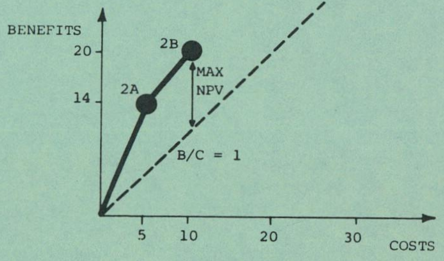
If fewer funds are available, an iterative procedure similar to the one used in project planning can be used to select projects for the program. (This procedure will not always produce the mathematically optimal investment program guaranteed by more expensive procedures such as dynamic or integer linear programming, because it does not try different

PROJECT ALTERNATIVES AT 4 SITES

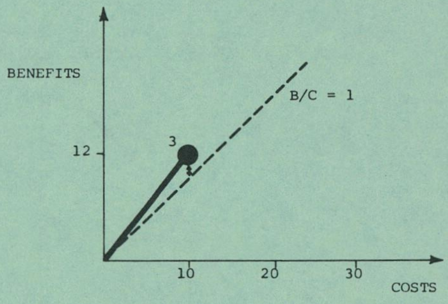
Site 1



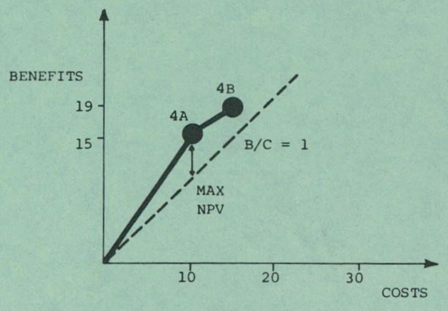
Site 2



Site 3



Site 4



TOTAL BUDGET = $2.5 million

Step	Choice	Additional			Program	Cumulative		
		Cost	Ben	B/C		Cost	Ben	B/C
1	1A	0.5	1.5	3.0	1A	0.5	1.5	3.0
2	2A	0.5	1.4	2.8	1A, 2A	1.0	2.9	2.9
3	1B	0.5	1.0	2.0	1B, 2A	1.5	3.9	2.9
4	4A	1.0	1.5	1.5	1B, 2A, 4A	2.5	5.4	2.2

combinations of projects in an attempt to use every dollar in a budget. Given typical uncertainties regarding program budgets and project costs and benefits, this shortcoming is of little concern.)

The following table shows the use of the procedure in selecting projects for a $2.5 million program. In each step, the investment is selected which produces the highest incremental benefit/cost ratio. Note that, in step 3, additional funds are invested in site 1 even though two sites as yet have received none. The final program, consisting of alternatives 1B, 2A, and 4A, costs the available $2.5 million and produces $5.4 million in benefits; its net present value of $2.9 million cannot be exceeded by investing the $2.5 million in any other manner at the four sites. If only $1 million of funds were available, the program would consist of alternatives 1A and 2A, as shown above the dotted line in the diagram.

A variant of the procedure can be used if an agency wants to spend at least a minimum amount in each jurisdiction or to take matching funds in different state and federal funding programs. The procedure would be applied once to projects that helped meet one or more unmet objective, and a second time to allocate any remaining funds among all projects. In the example, if an agency wanted to spend at least $.5 million in a program area covered only by project 3, it would select that project in the first pass. The $1.5 million remaining in the budget would be allocated in the second pass, and projects 1B and 2A would be selected.

- References

1. Juster, R.D. and Batchelder, J.H., Highway Investment Analysis Package (HIAP). Four volumes prepared for USDOT/FHWA by Multisystems (reviewed and edited by Wilbur Smith and Assoc.) Reports FHWA-PL-79-013 through -016, Cambridge, Mass. (June 1979).

2. Multisystems, Inc., and Cambridge Systematics, Inc., "HIAP Application Guide." Users' manual prepared for Wisconsin Department of Transportation (Jan. 1979) 70 pp. plus appendices.

3. AASHTO, A Manual on User Benefits of Highway and Bus Transit Improvements. Washington, D.C. (1977).

E/P Note 4: Program Development Techniques

- Description

A review of priority programming methods found few techniques that deal with TSM-type improvements, and most of those were sufficiency ratings or extensions called "priority arraying" that incorporate network importance, public costs, user benefits, and/or social and environmental factors (1, 2). In many cases, however, the sufficiency or deficiency ratings dominate the overall scores, so the extensions contribute little to programming decisions. In the rating formulas developed for the Georgia DOT (3), for example, the deficiency ratings accounted for over four-fifths of the point scores assigned to lower cost improvement categories such as "safety improvements" and "traffic engineering improvements." Programming decisions could effectively be made during problem assessment. In practice, the ratings did not work well for the categories that contain TSM projects. The ratings are now used only for ranking new construction and major improvement projects.

Priority arraying has other problems that tend to limit its applicability to TSM programming. It can only be applied to projects that repair or replace a piece of the existing system, and it is weak in handling projects designed to correct multiple deficiencies as well as in distinguishing among alternative approaches to correcting one or more deficiencies.

Another major category of programming techniques uses benefit/cost or cost/effectiveness measures (see E/P Note 3) to select projects and packages for inclusion in implementation programs. These techniques typically use savings in travel time, user costs, accidents, and operator costs as benefit or effectiveness measures. The most sophisticated of these techniques: the Highway Investment Analysis Package (HIAP, 4) and the Ontario Priority Programming System (PPS, 5) also allow factors such as regional equity and multiple funding sources to be considered in developing programs, so they could be adapted to assist in the preparation of TSM programs. Although HIAP and PPS contain techniques for estimating the benefits of some types of minor highway improvements, their use to date has been in programming major highway improvements (5, 6). The AASHTO "red book" (7) describes procedures for estimating the user travel time, cost and accident benefits, maintenance and operating cost changes, and capital costs of bus transit and other types of low-cost highway improvements, and those techniques could be used to expand the applicability of the benefit/cost or cost/effectiveness programming models. The effectiveness of diverse TSM measures, however, are difficult to compare and quantify, so many of the problems encountered in priority arraying preclude the rigorous application of these techniques (i.e., their use with the exclusion of professional judgment).

Two recent statewide programming efforts illustrate how diverse formal techniques can be combined with professional judgment and qualitative assessment to develop investment programs that receive general acceptance. In preparing a six-year highway improvement program for Wisconsin (6, 8), transportation department staff used benefit-cost and cost-effectiveness techniques to develop "candidate" programs that clearly identified the consequences of different program objectives (e.g. safety vs. travel time savings), funding levels and allocation policies (e.g. urban vs. rural). The selection of specific projects for inclusion in the recommended program was based on the consistency of a project's selection in the candidate programs weighed against other criteria such as deficiency summaries, scheduling constraints, environmental, community and network continuity factors.

Pennsylvania (9) recently initiated a special program to make better use of federal highway funds. The program was targeted at low-cost highway projects that reduced congestion delays, accidents and energy consumption. After experiencing difficulties in selecting projects submitted by county agencies in the first year of the program, state officials established evaluation criteria (e.g., a minimum benefit-cost ratio, a minimum federal participation rate, and a minimum daily traffic level) that would apply to all projects and distributed a set of standard techniques for estimating the corresponding evaluation measures. As a result of the standards, the programming task was simplified to the selection of the best 50 percent of submitted projects from the selection of the best 5 percent a year earlier.

- References

1. Transportation Research Board, "Priority Programming and Project Selection." NCHRP Synthesis of Highway Practice 48, Washington, D.C. (1978) 31 pp.

2. Transportation Research Board, "Bibliography on Project Evaluation and Priority Programming Criteria." Transportation Research Circular 213, Washington, D.C. (Jan. 1980) 35 pp.

3. Federal Highway Administration, "Seven Approaches to Highway Programming." Draft Report 4 of Statewide Transportation Planning and Management Series, Washington, D.C. (June 1981) 80 pp.

4. Juster, R.D. and Batchelder, J.H., Highway Investment Analysis Package (HIAP). Four volumes prepared for USDOT/FHWA by Multisystems (reviewed and edited by Wilbur Smith and Assoc.), FHWA-PL-79-013 through -016, Cambridge, Mass. (June 1979)

5. Bellomo, S.J., et al., "Evaluating Options in Statewide Transportation Planning/Programming: Techniques and Applications." NCHRP Report 199, Washington, D.C. (March 1979) 190 pp.

6. Batchelder, J.H. et al., "Application of the Highway Investment Analysis Package." Transportation Research Record 698, Washington, D.C. (1979) pp. 1-5.

7. AASHTO, A Manual on User Benefits of Highway and Bus Transit Improvements. Washington, D.C. (1977).

8. Neumann, L. and Dresser, J., "New Approaches for Analyzing Highway Program Choices and Trade-offs." Transportation Research Record 742, Washington, D.C. (1980) pp 1-5.

9. Haack, H., Bryer, T., and Taylor, R., "ECONS, A Case Study in Program Development through an Integrated, Organizational Approach." Transportation Research Record 867, Washington, D.C. (1982) pp 30-33.

TSM Information Sources

This section contains a basic reference library for planners in small urban areas, and a list of agency offices that distribute information on TSM actions and analysis methods.

The references in the basic library are keyed to the following categories:

- General
- Traffic and Parking
- Transit/Paratransit
- Commuter Ridesharing
- Elderly and Handicapped Transportation
- Pedestrian
- Goods Movement

The primary agency sources for up-to-date TSM information include:

- Federal Agencies
- Institutions
- Nonprofit Organizations

Basic Reference Library

General

1. Barton-Aschman Assoc., Inc., *Traveler Response to Transportation System Changes*. Second Edition, prepared for USDOT/FHWA, Office of Highway Planning, Contract No. DOT-FH-11-9579 (July 1981) 400 pp.
2. Levinson, H.S. and Weant, R.A., ed., *Urban Transportation Perspectives and Prospects*. Eno Foundation for Transportation, Westport, Conn., (1982).
3. Levinson, H.S., *Characteristics of Urban Transportation Demand - A Handbook for Transportation Planners*. Wilbur Smith & Assoc., USDOT/UMTA Report No. UMTA IT-06-0049-78-1 (April 1978).
4. Roark, J.J., "Experiences in Transportation System Management." *NCHRP Synthesis of Highway Practice 81*, Washington, D.C. (1981) 88 pp.
5. Sanders, D.B. et al., *Characteristics of Urban Transportation Demand - A Handbook for Transportation Planners*. DeLeuw Cather & Co./Rock Creek Assoc., USDOT/UMTA Report No. UMTA IT-06-0049-78-1 (July 1977).
6. Sosslau, A.B., et al., "Quick Response Urban Travel Estimation Techniques and Transferable Parameters: User's Guide." *NCHRP Report No. 187*, Washington DC (1978) 229 pp.
7. Spanovich, Columbia Region Assoc. of Govts., *Transportation System Management Prototype Planning Study: Portland (OR)*. USDOT/UMTA Report No. UMTA-IT-09-0068-79-1 (Nov. 1979).
8. Urbitran Assoc., Inc., *Transportation Systems Management Implementation and Impacts, Final Report*. USDOT/UMTA Report No. DOT-I-82-49 (March 1982).

Traffic and Parking

1. Box, P.C., and Oppenlander, J.C., *Manual of Traffic Engineering Studies*. Fourth Edition, Institute of Transportation Engineers, Arlington, Va. (1976).
2. Engineering Experiment Station, Ohio University, "Development of Guidelines for the Application of Continuous Two-Way Left-Turn Median Lanes." NTIS No. PB-247-300 (July 1975) 105 pp.
3. Homburger, W.S. ed., *Transportation and Traffic Engineering Handbook*. Second Edition, Institute of Transportation Engineers, Prentice-Hall Inc., Englewood Cliffs, N.J. (1982) 880 pp.
4. Institute of Transportation Engineers, *Guidelines for Urban Street Design*. Washington D.C. (1979) 150 pp.
5. DiRenzo, J.F., et al., "Study of Parking Management Tactics," Volume 2: *Overview and Case Studies*. Peat, Marwick, Mitchell and Co., Report No. DOT-FH-11-9537 (June 1981).
6. Smith, D.T., and Appleyard, P., *Improving the Residential Street Environment*. DeLeuw, Cather & Co., USDOT/FHWA Report FHWA-RD-81-031.
7. *Transportation Research Board, "Interim Materials on Highway Capacity." *Transportation Research Circular 212*, Washington, D.C. (Jan. 1980) 272 pp.
8. Wagner-McGee Associates, *Traffic Control System Improvements: Impacts and Costs*. Prepared for USDOT/FHWA (March 1980).

Transit/Paratransit

1. Billheimer, J.W., et al., *Paratransit Handbook, A Guide to Paratransit Implementation*. USDOT/TSC, Reports No. UMTA-MA-06-0054-79-1 and -2 (Jan. 1979) 830 pp.
2. Fleishman D., et al., *General Community Paratransit Services in Urban Areas*. Multiplications, Inc., UMTA Office of Policy Research Report No. DOT-I-82-15, (Jan. 1982), 106 pp.
3. Gilbert, K., *Transportation System Management: Handbook of Manual Analysis Techniques for Transit Strategies*. A.M. Voorhees & Assoc., USDOT/UMTA Report No. TX-09-0045-81-1 (1981) 200 pp.
4. Levinson, H.S., "Bus Route and Schedule Planning Guidelines." *NCHRP Synthesis of Highway Practice 69*, Washington, D.C. (May 1980) 100 pp.
5. Levinson, H.S., W.F. Hoey and C.L. Adams, "Bus Use of Highways - Planning and Design Guidelines." *NCHRP Report 155*, Washington, D.C. (1975) 160 pp.
6. Mayworm, P., Lago, A., McEnroe, J.M., *Patronage Impacts of Changes in Transit Fares and Services*. Ecosometrics Inc., Bethesda, Md., UMTA Report RR135-1 (Sept. 1980) 250 pp.

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* The NCHRP, FHWA, TRB Committee on Highway Capacity, and others are conducting research to develop a new Highway Capacity Manual. *NCHRP Research Results Digest 140* (February 1983) contains a status report and references to *TRB Circular 212* and other draft material.

Transit/Paratransit (continued)

7. Public Technology, Inc., Transit Actions - Techniques for Improving Productivity and Performance. Washington, D.C., (Oct. 1979).

8. Smerk, G., and Gerty, R.B., ed., Mass Transit Management: A Handbook For Small Cities. Second Edition. Four volumes, IN 09 8002 8003 8004 (Revised 1980).

9. Vuchic, V.R., et al., Transit Operating Manual. Prepared for PennDOT, Harrisburg, Pa. (1976).

Commuter Ridesharing

1. Jacobson, J.O., University of Washington, Employer Vanpool Programs: Factors in Their Success or Failure. Prepared for USDOT/FHWA, Report No. UMTA-WA-11-0005-78-3, NTIS #PB-276955 (June 1977) 85 pp.

2. Misch, M.R., et al., "Guidelines for Using Vanpools and Carpools as a TSM Technique." NCHRP Research Report 241, Washington, D.C. (Dec. 1981) 155 pp.

3. Multisystems and Skidmore, Owings, and Merrill, Ridesharing Implementation Guide. USDOT/FHWA Contract No. DTFH61-80-C-00182 (1981) 150 pp.

Elderly and Handicapped Transportation

1. Applied Resource Integration, Ltd., Guidelines for Coordinated Agency Transportation Service. Prepared for OHDS/HEW under Contract No. HEW-105-76-7402 (April 1980).

2. Burkhardt, J. et al., Coordinated Transportation Demonstration Results. OHDS/HEW Report No. HEW-105-76-7404 (Feb. 1980) 140 pp. plus appendices.

3. Fleishman, D., et al., Paratransit Services for the Transportation Handicapped. Multiplications, Inc., UMTA Office of Policy Research, Report No. DOT-I-82-18 (April 1982) 90 pp.

4. Proceedings of the Sixth and Seventh Annual Conference on Transporation for the Elderly and Handicapped, Transportation for the Elderly and Handicapped - Program and Problems. Volume 1 (December 1978) 145 pp. Volume 2 (February 1981) 193 pp. Available through the Technology Sharing Office, Transportation Systems Center USDOT.

Pedestrians

1. American Public Works Assoc., "Planning and Construction of Municipal Malls." APWA Special Report 46, 2SBN-0-917084-34-9 (July 1979).

2. Brombilla, R. and Longo, G., A Handbook for Pedestrian Action. Prepared for USHUD by Institute for Environmental Action, Columbia University (1977) 150 pp. Available from the US Superintendent of Documents, Stock No. 023-000-00373-2. Companion document by the same authors is Banning the Car Downtown - Selected American Cities (Stock No., 023-000-00375-9), 150 pp.

3. Transportation Research Board, "Interim Materials on Highway Capacity." Transportation Research Circular 212 (Jan. 1980) 272 pp.

Goods Movement

1. Christiansen, D.L., Urban Transportation Planning for Goods and Services - A Reference Guide. Prepared for FHWA by Texas Transportation Institute, College Station, Texas (June 1979).

Agency Information Offices

U.S. Department of Transportation

- Office of the Secretary
  - Office of Technology and Planning Assistance
    400 Seventh Street, S.W.
    Washington, DC 20590
    (202) 426-4208
- Research and Special Programs Administration
  - Technology Sharing Office
    Transportation Systems Center (Code 151)
    Cambridge, MA 02142
    (617) 494-2486

    Microcomputers in Transportation Planning, Users' Group
    Transportation Systems Center, DTS-62
    Cambridge, MA 02142
    (617) 494-2247
- Federal Highway Administration
  - Office of Highway Planning
    400 Seventh Street, S.W.
    Washington, DC 20590

    Urban Transportation Planning and Management Division
    (202) 426-0166
    Transportation Management & Ridesharing Programs Branch
    (202) 426-0210
    Technical Support Branch
    (202) 426-0182
  - Office of Traffic Operations
    400 Seventh Street, S.W.
    Washington, DC 20590

    Traffic Control Systems Division
    (202) 426-0411
    Traffic Engineering Division
    (202) 426-1993
- Urban Mass Transportation Administration
  - Office of Methods and Support
    400 Seventh Street, S.W.
    Washington, DC 20590

    Methods Division
    (202) 426-9271
    Analysis Division
    (202) 426-9267
- Urban Mass Transportation Administration (cont'd.)
  - UTPS Support Center
    COMSIS Corporation
    11501 Georgia Avenue
    Wheaton, MD 20902
    (800) 638-8747
    (301) 933-9211
  - Office of Service and Management Demonstration
    400 Seventh Street, S.W.
    Washington, DC 20590

    Traffic Services Division
    (202) 426-4948
    Management Division
    (202) 426-9274

Other Organizations

- Public Technology Inc.
  1140 Connecticut Avenue, N.W.
  Washington, DC 20036
  (202) 626-2400
- American Public Transit Association
  1225 Connecticut Avenue, N.W.
  Washington, DC 20036
  (202) 828-2800
- Transportation Research Board
  National Research Council
  2101 Constitution Avenue
  Washington, DC 20418
  (202) 334-2933
- Transportation Industry Microcomputer Exchange
  Rensselaer Polytechnic Institute
  Civil Engineering, Room 4049
  Troy NY 12181
  (518) 457-1283
- Institute of Transportation Engineers
  525 School St. SW
  Suite 410
  Washington, DC
  (202) 554-8050

NOTES

PART III
APPLICATIONS

Case studies are presented that illustrate adaptation of the framework presented in Part I to specific planning situations. Although different approaches and methods are used in the studies, they show (to varying degrees) the key features of the framework:

- An emphasis on problem and site assessment.
- A problem-solving approach to analysis and design.
- Use of estimation techniques to prepare information for decisions.
- Selective use of evaluation criteria and measures.
- Clear presentation of findings and recommendations.

Case Study 2 is a strategic planning study. The others primarily are project planning studies, although Case Study 6 contains strategic planning elements, and are presented using the four-phase process described in Part I, Chapter Three.

Case Study 2:
St. Louis Regional Transit Assessment

Purpose: This study illustrates the use of strategic planning in an urban area faced with problems in financing public transit operations. Alternative service policy options are examined and used to set general, but realistic, guidelines for transit service planning.

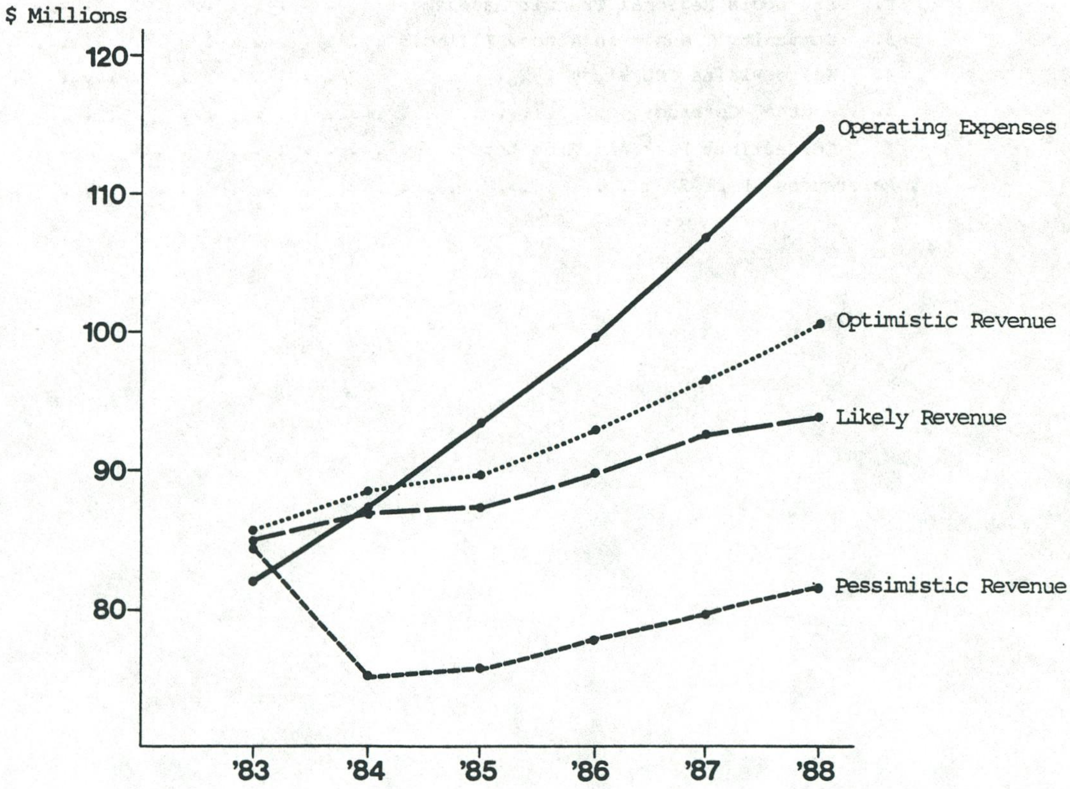
Background

Uncertainty in the availability of federal operating assistance, combined with controversy over transit quality, cost, and funding in the St. Louis region, prompted the East-West Gateway Coordinating Council (EWGCC, the region's MPO) to examine regional public transportation policies. A two-phase study was commissioned that involved EWGCC, Bi-State Development Agency (the transit operator), and a consultant. The first phase was an overall evaluation of transit service in the region that identified problem areas and opportunities for improvement, while the second phase focused on alternative service and financial strategies. The study was designed to assist local government leaders and the Bi-State board and management in developing a cohesive regional service strategy to meet the region's near-term service needs within available resources.

ESTIMATING FISCAL RESOURCES AND REQUIREMENTS

Proposed reductions in federal operating subsidies and continued reliance on economy-sensitive sales taxes as a basis for state and local subsidies threatened to produce operating deficits that would force Bi-State to make major service reductions and/or significant fare increases. To quantify the prospective fiscal problem, expenses and revenues were projected over a 5-year period. Expense forecasts were based on a continuation of Bi-State's current service levels and current wage, fringe benefit and pension provisions. Farebox revenues, which account for less than 30 percent of total revenues, were extrapolated. Different levels of federal support and sales tax revenue were projected and used to develop the optimistic, likely, and pessimistic forecasts shown below. The expanding gap between expenses and revenues showed that the agency and region faced a serious fiscal problem.

EXPENSE AND
REVENUE FORECASTS

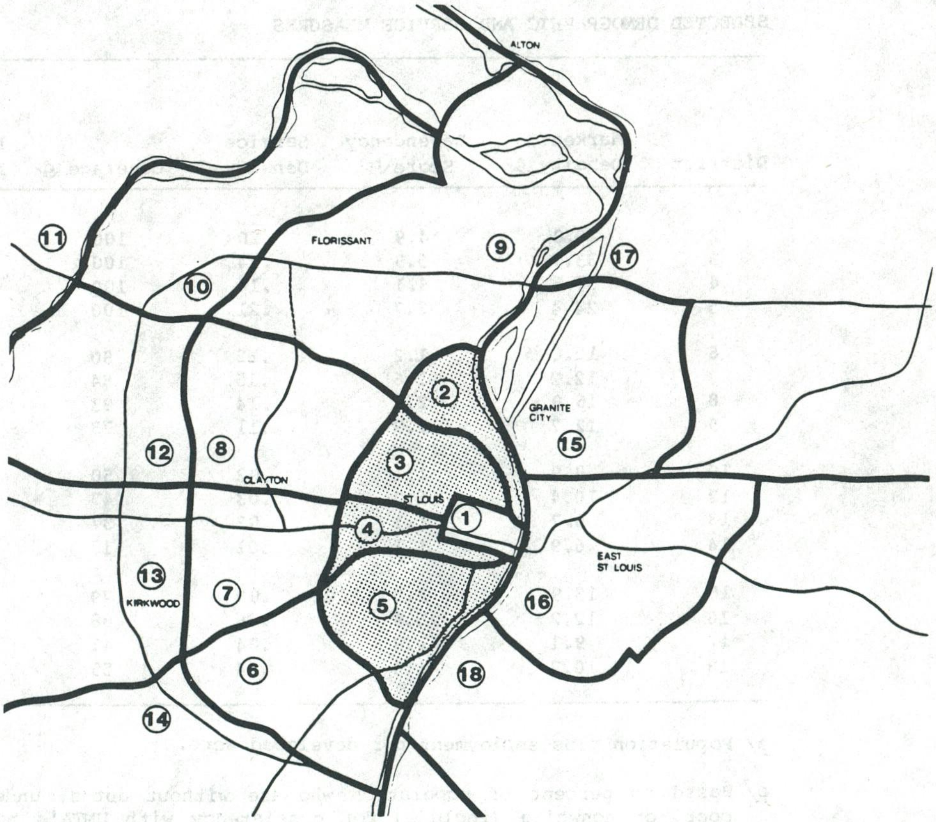


ASSESSING SERVICE ADEQUACY

An aggregate analysis of existing transit service was conducted to assess overall service adequacy and equity. For the analysis, the region was divided into 18 districts as shown below. The assessment was based on differences between four groups of districts, and on differences within each group; the groups are as follows:

Group	Districts
City of St. Louis	2,3,4,5
Inner St. Louis County	6,7,8,9
Outer St. Louis County	10,12,13,14
Illinois Counties	15,16,17,18

DISTRICTS DEFINED FOR SERVICE ADEQUACY ASSESSMENT



Three sets of measures were developed for each district. The first set were indicators of service "need":

- Combined population and employment density
- Percent of residents in low-income households
- Percent of residents in auto-less households
- Percent of residents under 16 or over 65
- Percent of residents in minority groups

The last four need indicators also were combined into a transit dependency score.

The second group measured the quantity and quality of service provided in each district; the measures included:

- vehicle-hours (total and per capita)
- vehicle-miles (total and per capita)
- route-miles (total and density)
- travel time to CBD (peak)
- average peak speed (local and express)
- average headway (peak and off-peak)
- average vehicle load (peak)
- number of bus trips to major destinations (peak)
- coverage (% of population within 1/4-mile of route)

The third group measured the use of existing service in each district; the measures included:

- boardings per vehicle-hour (peak and off-peak)
- boardings per capita (peak and off-peak)

Selected measures are shown in the following table.

The assessment highlighted some inequities and inefficiencies in the region's transit service. Productivity outside of the city and district 16 was found low, particularly during peak periods, while coverage in those areas appeared high in comparison to measures of market density and need. Some reallocation of service within the city also appeared warranted, with district 2, for example, gaining service.

SELECTED DEMOGRAPHIC AND SERVICE MEASURES

District	Market Density a/	Dependency Score b/	Service Density c/	Coverage d/	Service Productivity e/	
					AM Peak	Midday
2	20.0	4.9	.20	100	140	52
3	33.7	5.9	.24	100	74	66
4	57.5	4.1	.14	100	53	39
5	24.4	2.7	.21	100	50	38
6	12.0	1.2	.12	80	18	20
7	12.2	1.6	.15	84	19	16
8	16.0	2.5	.14	93	19	19
9	12.7	1.9	.11	73	17	21
10	8.9	1.1	.02	50	17	4
12	10.4	1.0	.03	47	1	3
13	5.7	1.1	.03	37	11	13
14	6.9	1.1	.01	17	14	9
15	13.9	2.3	.09	79	2	4
16	12.2	5.4	.16	88	89	89
17	9.1	1.8	.04	41	26	20
18	10.2	1.5	.04	59	14	23

a/ Population plus employment per developed acre.

b/ Based on percent of population who are without autos, under 16, over 65, poor, or nonwhite (included for consistency with UMTA's nondiscrimination requirements).

c/ Weekly vehicle-miles per potential user (population plus employment).

d/ Percent of population within 1/4-mile of a route.

e/ Boardings per vehicle-hour on local service.

ANALYZING SERVICE REVISION OPTIONS

Some basic options for reducing the forecast deficit were examined to provide agency service planners with effectiveness indicators for use in developing route and corridor-level modifications. The following options were examined:

- Reduce hours of operation - end service at 8 pm on weekdays, shorten weekend service to a 9 am - 6 pm period, and possibly eliminate Sunday service.
- Reduce service frequency - reduce peak frequencies on routes operating at 10 minute headways or less and carrying maximum loads of under 60 passengers per bus trip.
- Reduce coverage by consolidating routes - reduce route-miles in districts with higher route densities than typically operated in districts with similar population densities.
- Drop or replace service - discontinue routes operating with a productivity below 20 passengers per vehicle hour during the peaks, or replace them with community-based transit or paratransit service.
- Increase fares - increase base fares by 5 to 7 percent, with corresponding increases in special fares.

Where appropriate, changes in vehicle-miles, vehicle-hours, and number of buses were estimated, and a simple cost model developed by Bi-state was applied to translate these supply changes into changes in operating costs. Elasticities and other simple procedures were applied to estimate changes in ridership and revenues.

To illustrate, the analysis of reduced service frequency was conducted on a route-by-route basis. Peak loads, obtained from ride counts, were examined on all routes operated at 10-minute headways or less during peak commuting periods. Frequencies on these routes were reduced as long as the average passenger load per bus remained below 60. Conservative estimates of driver savings were made, and a simple cost model was applied to convert driver and vehicle reductions into cost savings. A headway elasticity of -0.25 was applied to estimate decreases in ridership that might result from headway reductions. A detailed table of the service frequency analysis is shown below; a summary table is shown on the following page.

POTENTIAL TRIPS SAVED ON MAJOR LOCAL ROUTES--P.M.

Route No.	Route Name	3-3:30 pm		3:30-4 pm		4-4:30 pm		4:30-5 pm		5-5:30 pm		5:30-6 pm		Estimated Trips Saved
		Trips	Load	Trips	Load	Trips	Load	Trips	Load	Trips	Load	Trips	Load	
3018	Taylor	1	58.0	3	37.0	3	30.3	2	33.0	2	31.0	2	14.5	2
3020	Cherokee	3	39.0	2	22.5	3	36.0	1	38.0	3	36.3	1	23.0	2
3030	Cass	3	16.3	3	29.3	2	33.0	2	43.5	3	28.3	3	35.7	3
3032	Wellston	2	26.0	3	28.0	2	34.0	4	27.0	3	26.3	3	31.0	4
3041	Lee	3	28.3	2	50.0	3	35.7	2	45.0	2	42.5	2	27.5	2
3070	Grand	2	34.0	4	43.0	3	49.7	4	40.5	2	40.5	3	41.7	2
3090	Hampton	2	60.5	3	36.0	1	50.0	3	45.3	1	36.0	1	27.0	1
3091	Olive	3	31.7	2	44.5	2	28.0	3	33.7	2	22.0	3	15.3	3
3093	Lindell	2	31.0	2	45.5	3	32.0	2	44.5	3	42.0	2	25.0	2
3094	Page	3	29.0	2	45.5	3	43.3	3	38.3	3	43.0	3	32.3	3
3095	Kings Hwy	7	64.8	7	68.0	4	47.7	5	53.2	4	38.7	-	--	1
3097	Delmar-Forsy.	3	26.3	2	38.5	3	30.3	2	45.0	3	35.3	1	28.0	3
3104	Natural Brdg.	3	21.3	3	25.3	2	46.5	3	39.7	2	41.5	3	41.3	4
3530	McKinley Brdg.	1	28.0	2	28.5	2	43.5	3	27.3	3	37.0	1	34.0	2
3560	Belleville-St. L.	3	34.7	2	32.0	3	49.0	4	44.7	4	33.7	2	41.5	3
3702	Rosemont	3	23.7	2	38.6	3	31.3	2	49.5	2	32.5	2	21.0	2
														39

RESULTS OF REDUCED SERVICE FREQUENCY ANALYSIS

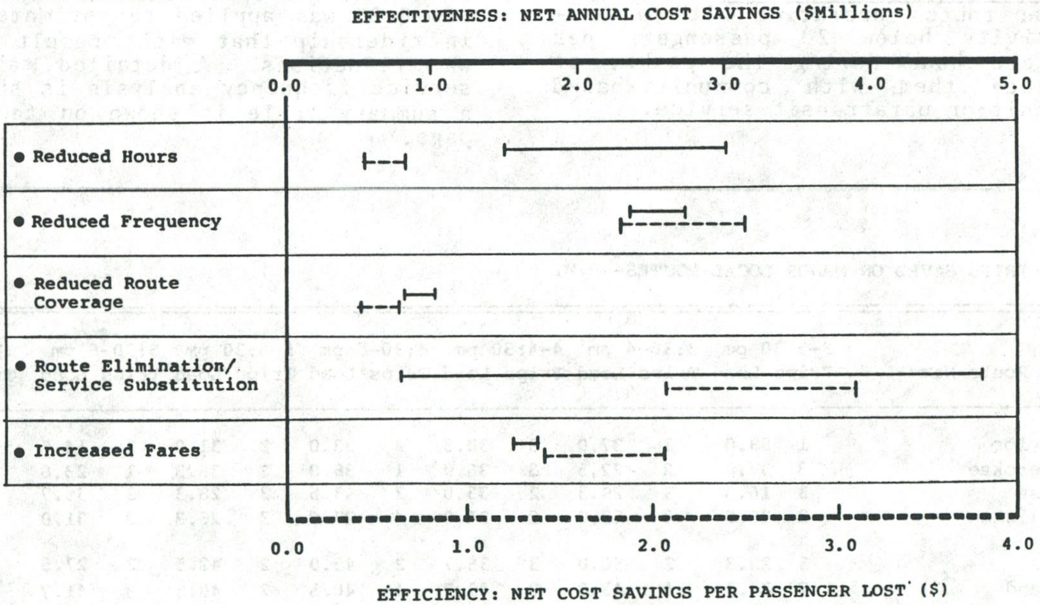
	Runs Saved per Day	Peak Buses Saved per Day	Vehicle-Miles Saved per Year	Percent Passenger Loss
Local Service	30-32	26	639,000	6-7
Express Service	5-7	5	58,000	6-7
Total:	35-39	31	697,000	6-7

Two summary measures were derived for comparing the service revision options:

- Effectiveness - net annual cost savings, i.e., operating cost savings minus revenue loss.
- Efficiency - net cost savings per lost passenger.

These measures, displayed below, show route elimination, reduced service hours, and frequency reductions have the most potential for producing cost savings. Service hour reductions, however, are costly in terms of ridership loss, so are less efficient than other options.

SUMMARY EVALUATION MEASURES



RECOMMENDATIONS

The service adequacy assessment and cost reduction options analysis provided general guidance to the agency and its service planners, but did not yield specific revisions to service warrants or performance criteria. One reason was that revenue estimates (i.e., the scale of the problem) were very dependent on debates in Washington on transit financing; another was that some of the cost reduction strategies were untested in St. Louis. To gain more information on the effectiveness of these actions, as well as implementation considerations such as lead time, legal and institutional barriers, and equity of impacts, implementation plans were started for a few pilot programs designed to improve the productivity and efficiency of transit service. The programs included route revisions and bus lanes in downtown St. Louis designed to reduce layover times, restructuring of suburban express services in a corridor, and the replacement of low-volume routes with paratransit service.

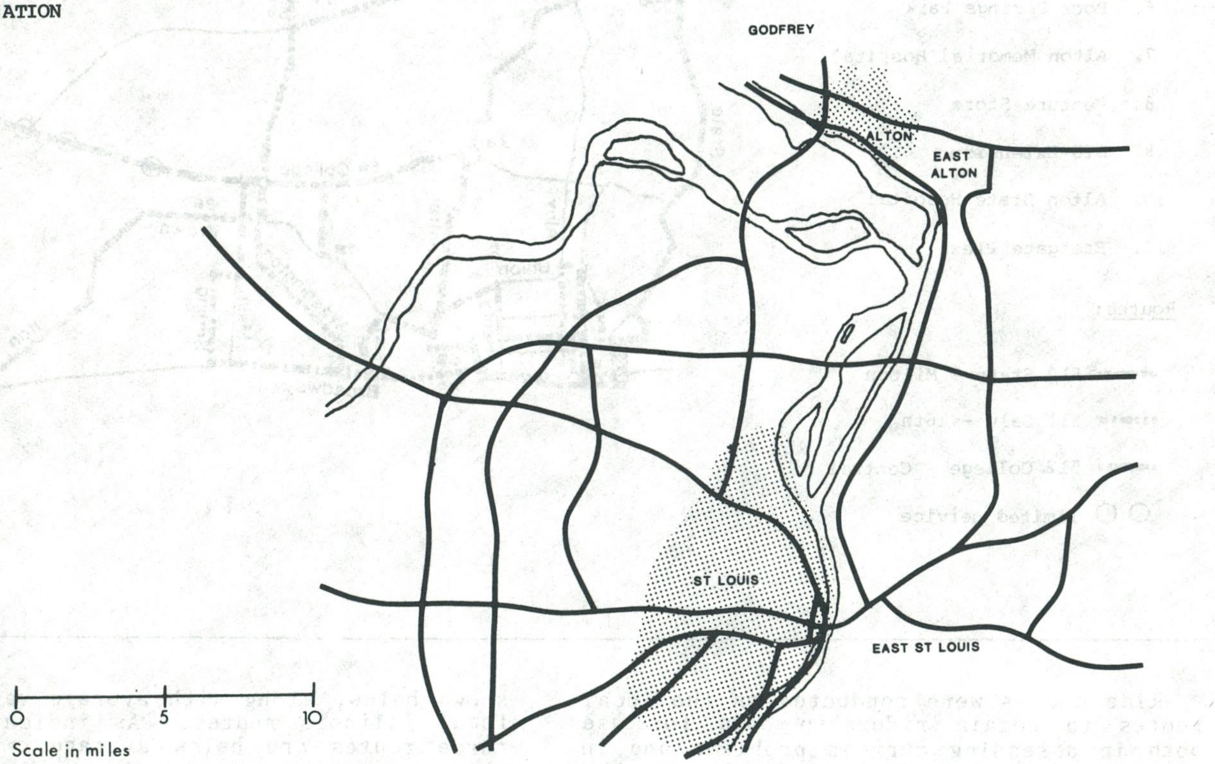
Case Study 3:
Community Transit in Alton, Illinois

Purpose: This case study illustrates the use of analytical models to develop a substitute for regular-route transit service provided by a regional transit authority. The objective was a reduction in the cost of providing intra-community service.

Site Description

Alton, located 20 miles from the St. Louis CBD, and the adjacent community of Godfrey are largely free-standing communities. Their combined population is 36,000. The regional operator, Bi-State Development Authority, operates two routes to St. Louis and three local routes within Alton.

SITE LOCATION



PHASE 1: ANALYZE PROBLEMS AND THEIR SETTING

Alton was selected as a possible site for a pilot service substitution project because it receives a substantial amount of local service that operates at low load factors typical of outer suburban services in the region. Its distance from the bulk of the Bi-State service area made it a particularly attractive site. In addition, portions of state and county sales taxes were earmarked for transit, and those revenues provided an alternative to federal operating assistance.

Alton is served by three local routes that function both as feeders to St. Louis bound routes and as local circulators serving shopping malls, hospitals, and colleges. The local routes operate from 6 AM to 7 PM at headways ranging from 30 to 90 minutes. As shown in the map on the following page, they provide good coverage in a service area of about 7 square miles. Census data indicate that 60 to 65 percent of Alton residents live within a quarter mile of a local route.

The routes do not function well as feeders. Scheduled wait times for transfers to an all-day route to downtown St. Louis range from 13 to 28 minutes, while wait times for transfers to a peak service to the airport and a nearby employment center range from 12 to 28 minutes.

CURRENT LOCAL TRANSIT SERVICE

Key Destinations:

1. 3rd Street Mall
2. Lewis & Clark Comm. College
3. Alton Square
4. St. Anthony's Hospital
5. St. Joseph's Hospital
6. Rock Springs Park
7. Alton Memorial Hospital
8. Venture Store
9. SIU Extension
10. Alton State Hospital
11. Eastgate Plaza

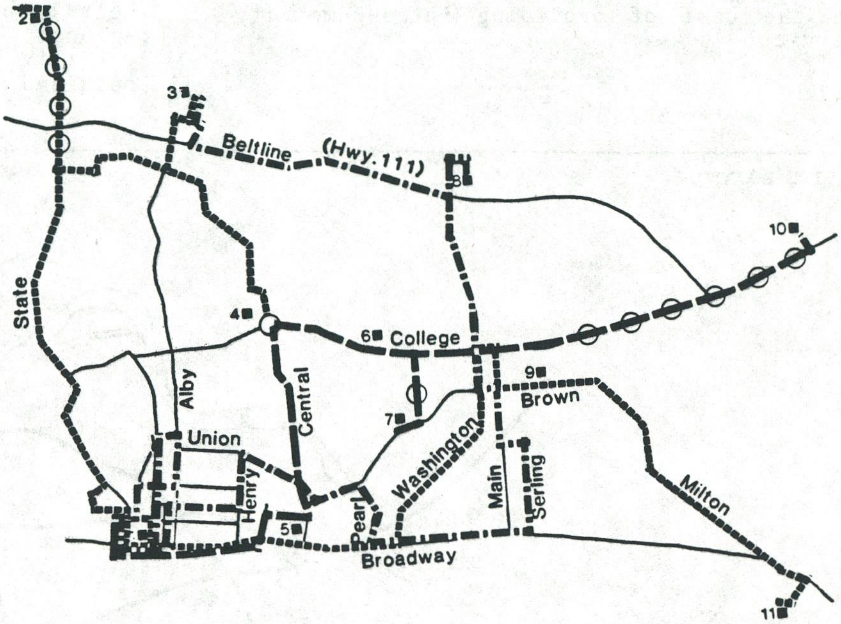
Routes:

▪▪▪▪▪ 510 State - Milton

▪▬▪ 511 Salu - 16th

▬ 512 College - Central

○ ○ limited service



Ride checks were conducted on the local routes to obtain ridership data for use both in assessing current problems and in designing a substitute service. The ridership data, combined with cost estimates obtained using a simple model based on bus-miles, bus-hours, and fleet size, were used to calculate performance indicators for the routes. These values are shown below, along with average values for local Illinois routes. As indicated, all three routes are below average. Possible causes are the poor coordination with the line-haul routes noted earlier, and duplicative service in some areas. The least productive route (512) serves no shopping centers.

OPERATING STATISTICS FOR ALTON LOCAL ROUTES

	----- Passengers per-----			Revenue	Deficit
Route	Bus Trip	Bus Hour	Bus Mile	/Cost Ratio	per Passenger
510	10.63	12.21	1.04	.063	$ 4.41
511	8.35	10.35	0.86	.055	5.12
512	3.75	7.73	0.71	.045	6.28
Average for Route Type		12.98	1.10	.083	$ 3.69

Of the 700 passengers per day on the local routes, roughly 300 of the trips are school children that might be served more cheaply by an independent operator under contract to the school district. The remaining use of the public transit system in Alton is relatively low and dispersed.

The identified problems were summarized as follows:

- Overall, route coverage was good, but entailed some duplication of service.
- Route productivity was poor, resulting in high costs per passenger.
- Schedules were not well coordinated for easy transfers to St. Louis service.

PHASE 2: IDENTIFY AND SCREEN CANDIDATE SOLUTIONS

Potential transit service revisions were screened to select options that would lower the basic hourly cost of providing service, increase the productivity in terms of trips served per hour of service, and/or improve the level of service offered. Cost reduction was critical, and reinforced the "pilot-program" solution of a small-vehicle community transit service provided by a private vendor selected through competitive bids.

Three basic service alternatives to the present Bi-State operation were specified as starting points for designing a community service; these were:

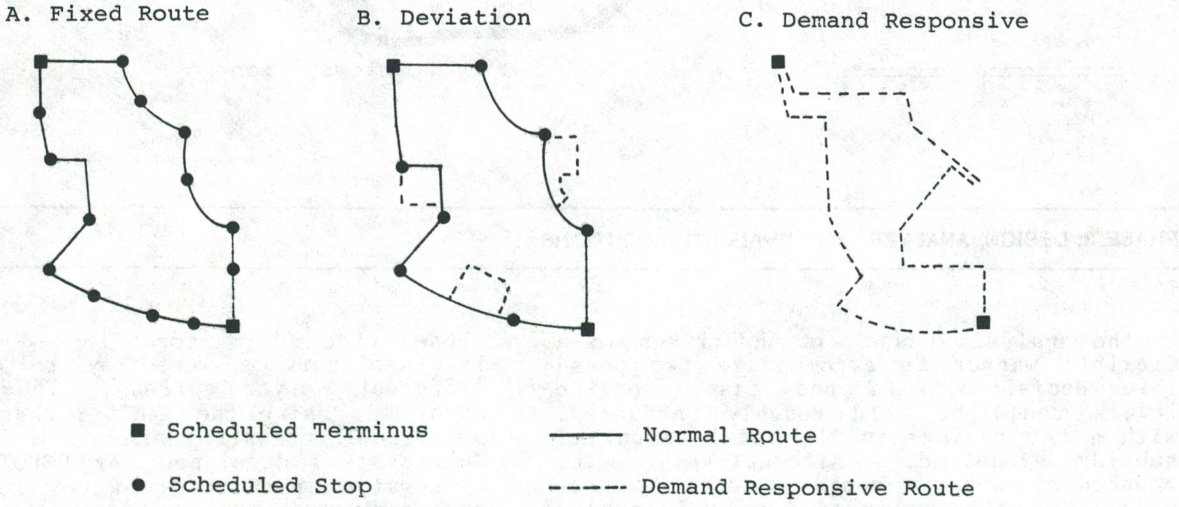
A. A (revised) fixed-route operation.

B. A fixed-route operation that would allow riders paying a premium fare to request doorstep service within a reasonable distance of the route.

C. A door-to-door service such as shared-ride taxi.

These service options are diagrammed below.

SCHEMATIC SERVICE OPTIONS

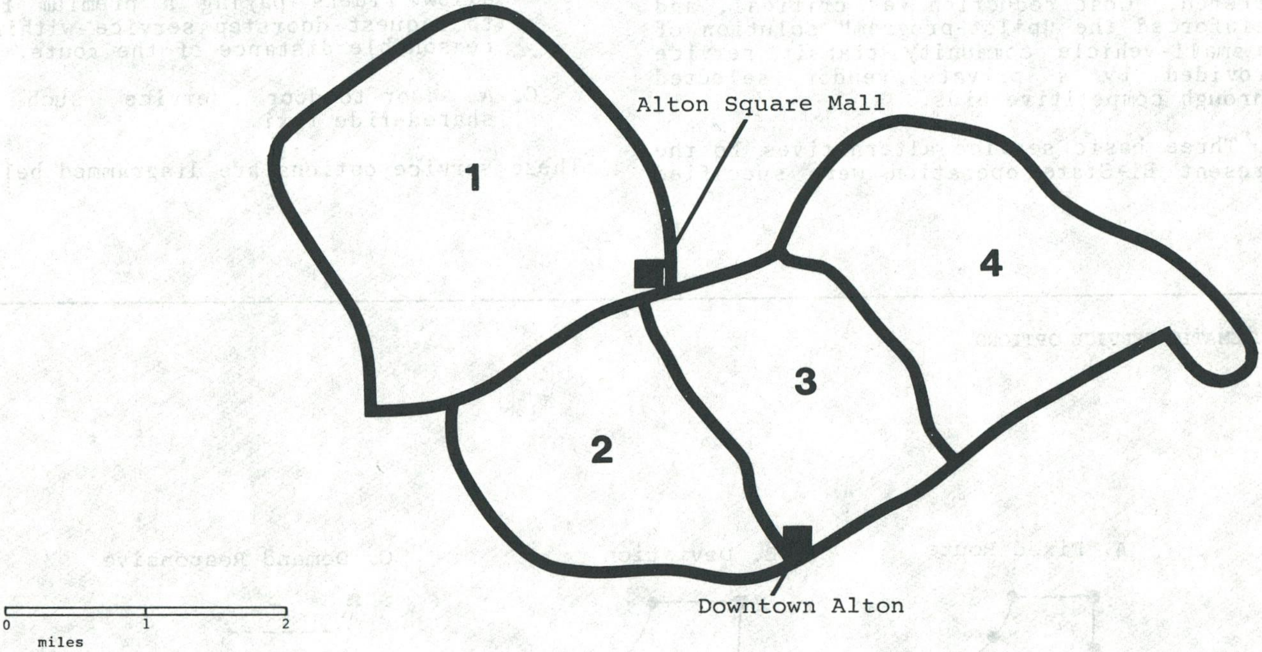


Data collected during problem assessment and guidelines set by the MPO led to the following specifications for the preliminary service options:

- Existing service hours of 6 AM to 7 PM were to be maintained.
- Design headways were to be 30 minutes (the peak headways on route 510), at least for initial planning purposes.
- School trips would be carried on a separate service.
- Service would be focused on downtown Alton and the Alton Square mall, the major trip generators for travel within Alton.

The fourth condition indicated a zone concept was appropriate. Vehicles would converge on downtown Alton and Alton Square at fixed schedules, which could be coordinated to allow for easy transfers among zones as well as to and from the St. Louis routes. Local street patterns, which limited the widths of some zones, and ridership data were used to develop the four zones shown below.

SERVICE ZONES

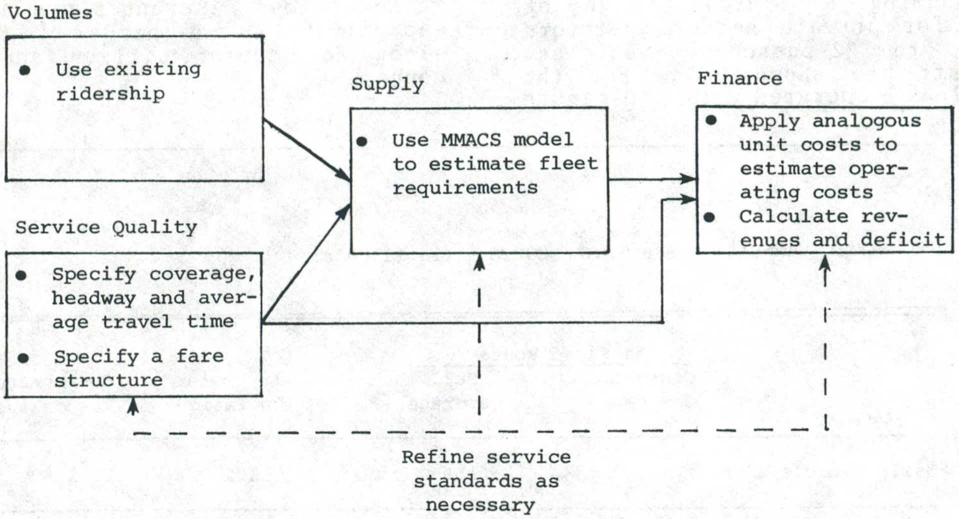


PHASE 3: DESIGN, ANALYZE, AND EVALUATE SOLUTIONS

The analysis phase was undertaken in a flexible manner to accommodate two possible decisions. In one case, service levels could be held roughly unchanged, with a net savings in the total amount of subsidy required. Alternatively, the reduced unit costs could be used to provide a slightly enhanced level of service while maintaining the total subsidy at or slightly below present levels.

The analysis plan developed for the case study is diagrammed at the top of the following page. Ridership was assumed constant at 400 passengers per day despite possible changes in travel time and fare. Estimates of the fleet required to carry those riders at specified door-to-door levels-of-service were key to evaluating different servce options. The estimates were made using the MMACS package, a computerized transit supply model which Multisystems developed for USDOT. Level-of-service parameters were revised as necessary to bring fleet requirements into line with an acceptable range of operating cost and subsidy. Operating costs were estimated using unit costs typical of private, small-vehicle transit operations. Revenues were estimated by applying a reasonable fare structure to the fixed ridership.

ANALYSIS PLAN



The MMACS model showed that vehicle requirements (and therefore costs) for some options were extremely sensitive to headway, i.e., the interval between consecutive departures from Alton Sq. or downtown Alton. For example, with headways of 30 minutes, two vehicles would be required for fixed-route service in each zone; with headways expanded to 45 minutes, only one vehicle would be required.

The model also showed that vehicle requirements for the fixed route option could be significantly reduced by interlining between zones 1 and 2 and between zones 3 and 4, or by reducing coverage to the current level of 60-65 percent of households within 1/4-mile.

Two variations on a route deviation service were examined. In one approach, a vehicle would have to return to the route at the same place where it began its deviation. In the second approach, variously known as checkpoint or point deviation, the vehicle could return to the route at the next regular bus stop (checkpoint). The latter alternative was selected because it would lead to slightly more efficient operations. Checkpoints were spaced ½ mile apart along the route.

ESTIMATED VEHICLE REQUIREMENTS (Peak and Off-peak Service)

Zone	A: Fixed Route				B: Route Deviation		C: Demand-Responsive	
	Current Demand		Full Coverage					
	PK	OP	PK	OP	PK	OP	PK	OP
1	2	2	6	6	2	1	2	1
2	2	2			2	2	3	2
3	2	2	6	6	2	1	2	2
4	2	2			4	4	3	2
TOTAL	8	8	12	12	10	8	10	7

The MMACS analysis indicated that sedan-type vehicles would be sufficient to serve the projected demand. Costs were projected assuming a typical range of hourly costs for private sector operators operating 5- to 22-passenger vehicles. Operating costs are shown below for the service options operated at 30-minute headways. The estimates for Options B and C include telephone operators and additional dispatchers that are required for those options. Revenues are assumed to be approximately two-thirds of full fare to allow for senior citizen and other discounts.

ESTIMATED ANNUAL OPERATING COSTS (in $1000's)

	A: Fixed Route			
	Current Coverage	Full Coverage	B: Point Deviation	C: Demand-Responsive
Daily Vehicle-Hours	104	156	122	118
Operating Costs				
Low	$ 518	$ 776	$ 607	$ 662
High	$ 644	$ 970	$ 759	$ 809
Revenues	$ 62	$ 86	$ 106	$ 115
Net Costs				
Low	$ 455	$ 695	$ 50	$ 547
High	$ 585	$ 885	$ 652	$ 694

PHASE 4: RECOMMEND AN ACTION PLAN

All three community transit service options appeared viable, and compared favorably to current net costs of the Bi-State routes estimated at $640,000 per year. Further design and analysis leading to an implementation plan, however, required local involvement and decisions regarding service quality and costs. Certain operating requirements, however, could be laid out to help final implementation planning for the route-deviation and demand-responsive options that were new to the agency.

Route Deviation

A premium fare of 50 cents per deviation should be charged over a base fare of 50 cents. In other places where this system is used, a high fare premium ensures that only a manageable number of requests (15-25 percent) for doorstep service must be met. The amount of the fare premium can be adjusted after service is initiated to meet this objective.

This option requires an operator to receive telephone requests for door step pick-up. If requests are required at least an hour in advance, the dispatcher can easily manage the calls during the off-peak, eliminating the need for a separate operator most of the day.

Cycled Demand-Responsive or Shared-Ride Taxi

Because of the relatively high quality of this service, the fare should probably be set at $1.00 or higher.

All trips not originating at downtown Alton or Alton Sq. will have to call for service. This will require 4 or 5 telephone operators in the morning peak, 2 or 3 in the afternoon peak, and 1 during the day. Standing requests for service by commuters on the morning would help reduce call-taker requirements. In addition to a dispatcher/supervisor, starters will be required at Alton Sq. and downtown Alton to coordinate passengers and drivers at those points.

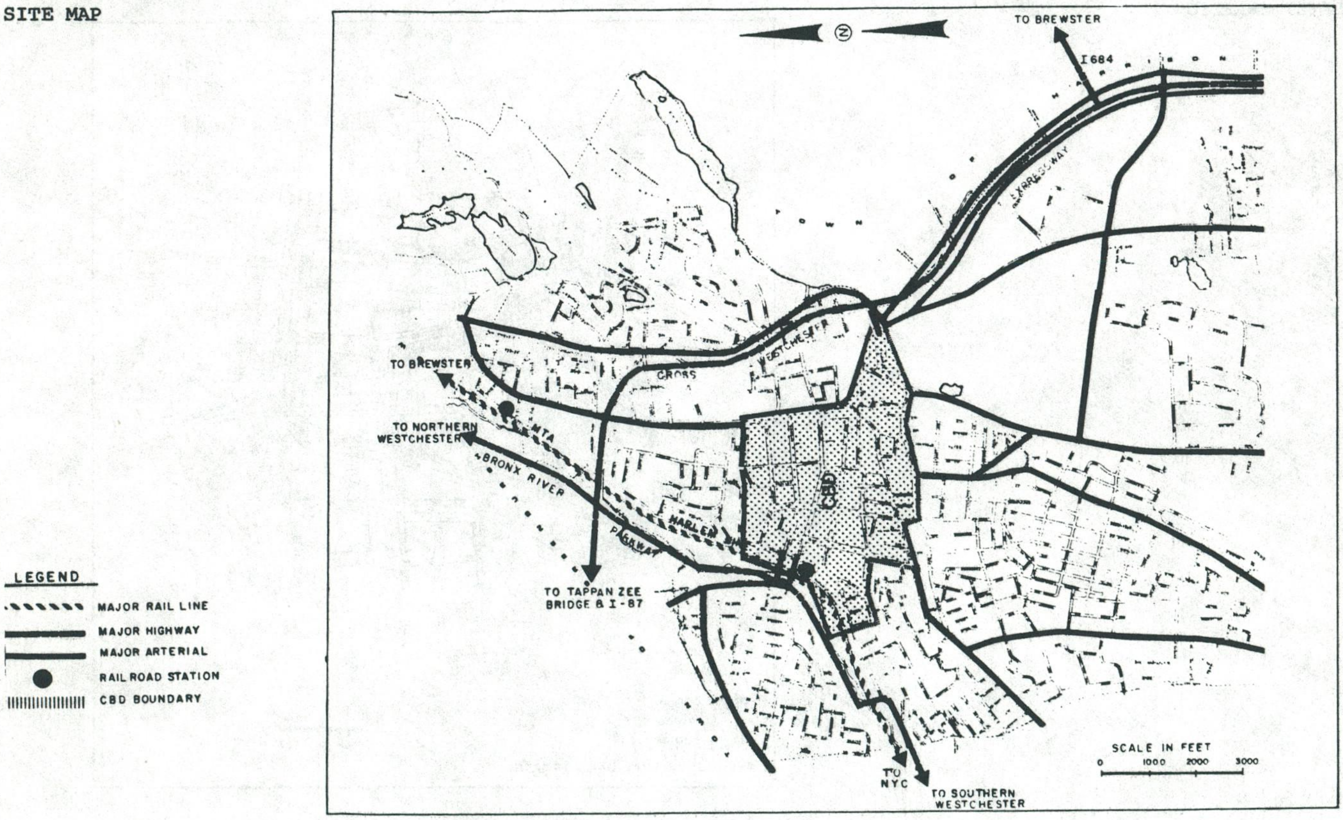
Case Study 4:
White Plains CBD Study

Purpose: This study illustrates the use of simple, conventional analysis methods to develop integrated street, transit, and pedestrian improvements designed both to solve current problems and to accommodate forecast growth.

Site Description

White Plains is a 10-square mile city located in southern Westchester County, N.Y. The city's resident population is 47,000, while its daytime population (including those residents who remain in the city and others who come to the city to work) is 250,000. Over the past decade, White Plains has emerged as one of the largest suburban commercial and office hubs in the region. Transportation lines that intersect the city include the Cross Westchester Expressway (I-287), the Bronx River and Hutchinson River Parkways, NYS Routes 22, 119 and 127, and the Harlem River commuter rail line of the MTA. These facilities are shown below on a map of the city and its CBD.

SITE MAP



PHASE 1: ANALYZE PROBLEMS AND THEIR SETTING

The study was prompted by the City's transportation officials who recognized that continued economic growth depended heavily on convenient access to and circulation within the CBD by all modes. Towards this end, a downtown comprehensive transportation plan was commissioned to improve mobility and reduce existing and anticipated congestion through better management and physical improvement of existing transportation resources.

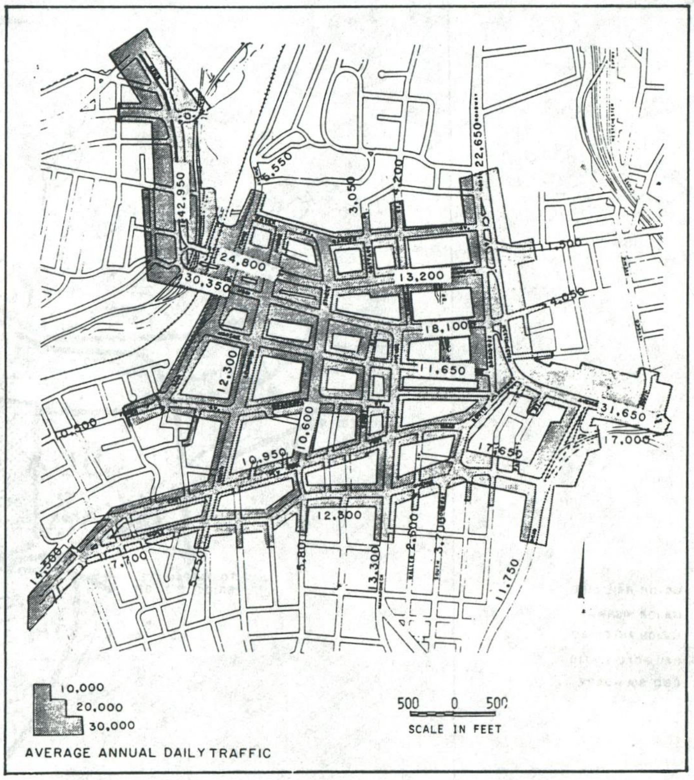
Key steps in identifying and analyzing problems included:

- Agency meetings - Pilot meetings were held with traffic, parking, planning, transit, and development officials to identify problems, define goals, and denote opportunities.

- <u>Reconnaissance</u> - Field observations of existing transportation and travel conditions in the CBD and its environs were made to identify problems and opportunities for actions to alleviate the problems.
- <u>Literature Review</u> - Transportation and development reports prepared over the preceding 15 years were reviewed for data and recommendations as well as relevance to the current situation.

Existing traffic volumes were analyzed for the city and the CBD. Maps of average daily traffic volumes for these areas, such as the one shown below, were developed. Peak-hour volumes per lane also were assessed at selected points in the CBD street system. These analyses pinpointed problem areas where the traffic volume exceeded capacities. For CBD streets, this limit was identified as 400 vehicles per lane per hour. Of the 28 portals that cross the CBD cordon, seven were identified as nearing or at capacity.

DAILY TRAFFIC



In addition, bus transportation in the city was assessed. This effort included identifying the coverage provided by each route (i.e., the percent of downtown destinations within 1,200 feet of a bus stop along the route), and the ability of the system to carry rail passengers from the station to destinations in the CBD (i.e., coverage and schedule coordination).

An analysis of the CBD's parking capacity and occupancy was undertaken. Public and private parking facilities with more than 30 spaces were mapped. The study found that the CBD's parking facilities, as a whole, had kept pace with demand, but that a parking shortage was likely to occur in specific areas within 5 years.

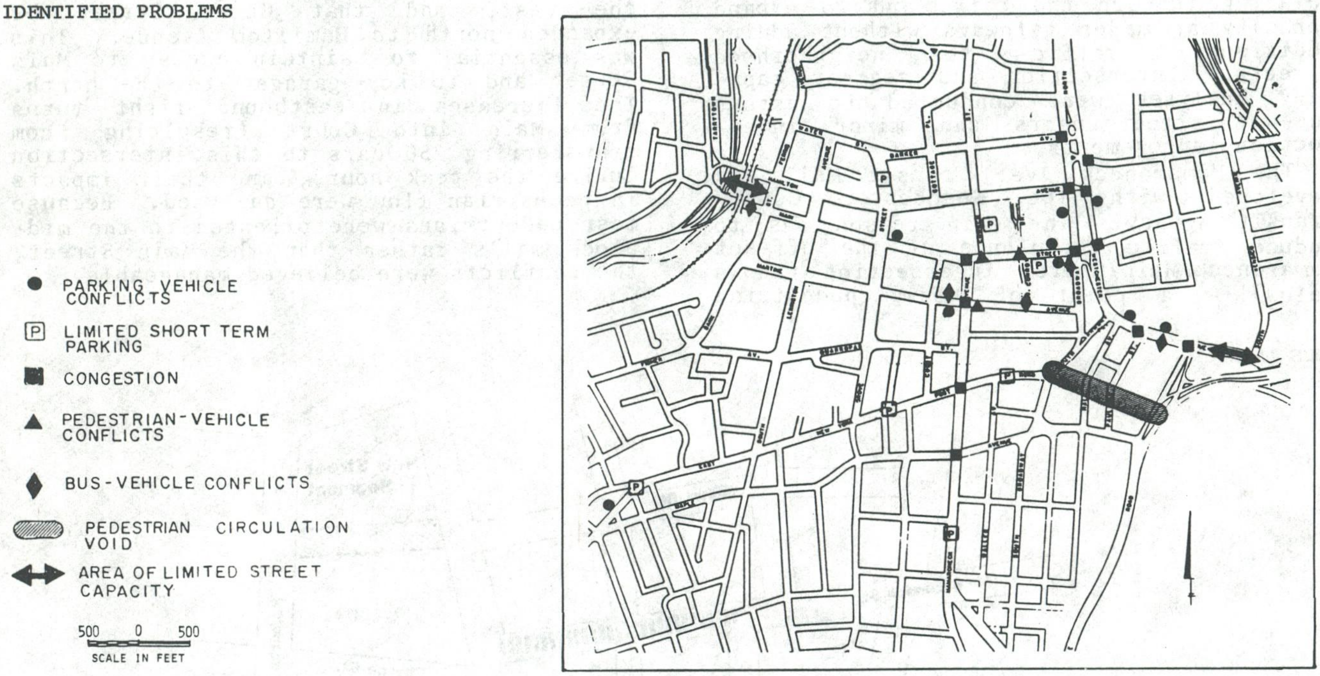
CBD pedestrian flows were also studied, with midday pedestrian volumes counted (by direction) at nearly 50 intersections. The major shortcoming noted was a dearth of sidewalks connecting the area of primary pedestrian activity with a large retail shopping complex. Finally, an analysis of taxi service indicated that the major demand generators were the railroad station, downtown hotels, hospitals, and department stores.

The review of pertinent reports, agency meetings, and the analysis described above resulted in the identification of the following problems affecting the CBD:

- vehicle conflicts with parked cars, buses, and pedestrians
- traffic congestion
- limited street capacity
- limited short term parking
- pedestrian circulation void

The location of these problems were mapped as shown below.

IDENTIFIED PROBLEMS



PHASE 2: IDENTIFY AND SCREEN CANDIDATE SOLUTIONS

Objectives and candidate strategies to achieve those objectives were then identified and screened using the following criteria:

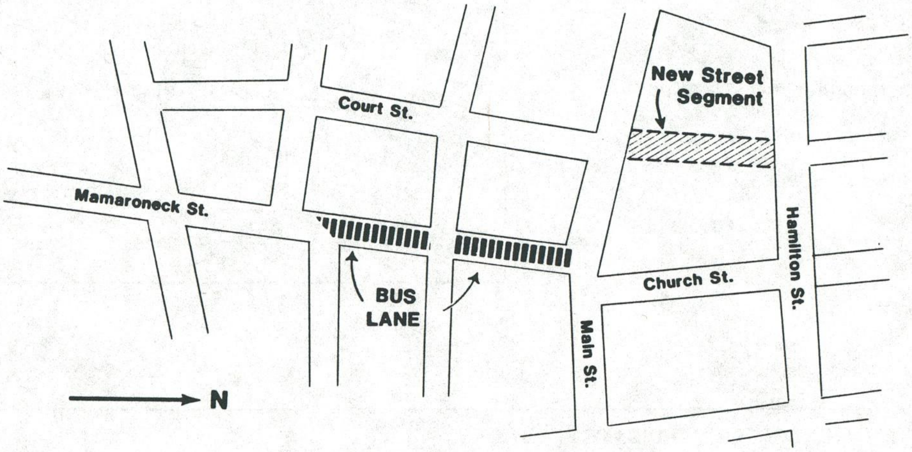
1. Coordinate transport facilities and capacities to existing and proposed developments.
2. Catalyze new developments by strategically adding improvements to the existing transport system.
3. Maintain and maximize accessibility of the city center from surrounding areas.
4. Provide travelers with choice of mode and route.
5. Encourage public transport ridership, particularly for home-to-work trips.
6. Provide a balanced supply and distribution of long-term and short-term parking facilities.
7. Expand transport capacity across the major barriers to movement, particularly to the north and west.
8. Develop a cohesive city center by making intra-CBD movements clear and convenient (for example, by providing better pedestrian connections between the Railroad Station and the Galleria, and between Post Road and Bloomingdale Road).
9. Refine bus routes to better serve activities within the CBD.
10. Coordinate rail, parking, pedestrian and transit proposals with on-going improvements planned by City agencies.
11. Encourage and assist paratransit facilities, such as taxicabs, carpools, vanpools, shuttle buses, and even automated pedestrian and vehicle systems, to enhance circulation and reduce congestion.

PHASE 3: DESIGN, ANALYZE, AND EVALUATE SOLUTIONS

Proposed street improvements were based on a review of existing travel patterns and traffic congestion, and expected traffic growth from new development. They were designed to improve the ease of circulating through the city, and to expand capacity at major gateways without adding additional traffic to neighborhood streets. Intersection and segment capacity analyses were conducted to assess one-way street pairs and minor intersection improvements.

The Mamaroneck Ave. Transit Mall was developed with the Weschester County Transit Agency. The main reason was to reduce traffic turbulence at the off-set Mamaroneck/Main/Church intersection (shown below) - a point of heavy pedestrian crossing. The product was a 2-block bus-only street in the heart of a shopping district. The street closure, however, required that traffic on Mamaroneck be transferred to Court Street, one-block to the west, and that Court Street be expanded north to Hamilton Avenue. This was essential to maintain access to Main Street and to key garages to the north. The increases in eastbound right turns from Main into Court (resulting from transferring 250 cars to this intersection during the peak hour), and their impacts in pedestrian flow were analyzed. Because most pedestrians were oriented to the mid-block malls rather than the Main Street, the conflicts were believed manageable.

BUS LANE



To verify the feasibility of proposed actions, traffic flow and volume maps were prepared for the year 2005 using manual assignments of estimated traffic. The proposed CBD traffic flow pattern would accomodate a 30 percent increase in peak-hour traffic with only three new street segments. Future transit operations and curbide usage also were forecast and mapped.

PHASE 4: RECOMMEND AN ACTION PLAN

Roadway and traffic management improvements for the CBD were recommended to provide an integrated system of street, bus, parking, and pedestrian facilities. The recommendations, including improvements already planned by the city, are summarized below and mapped on the following page.

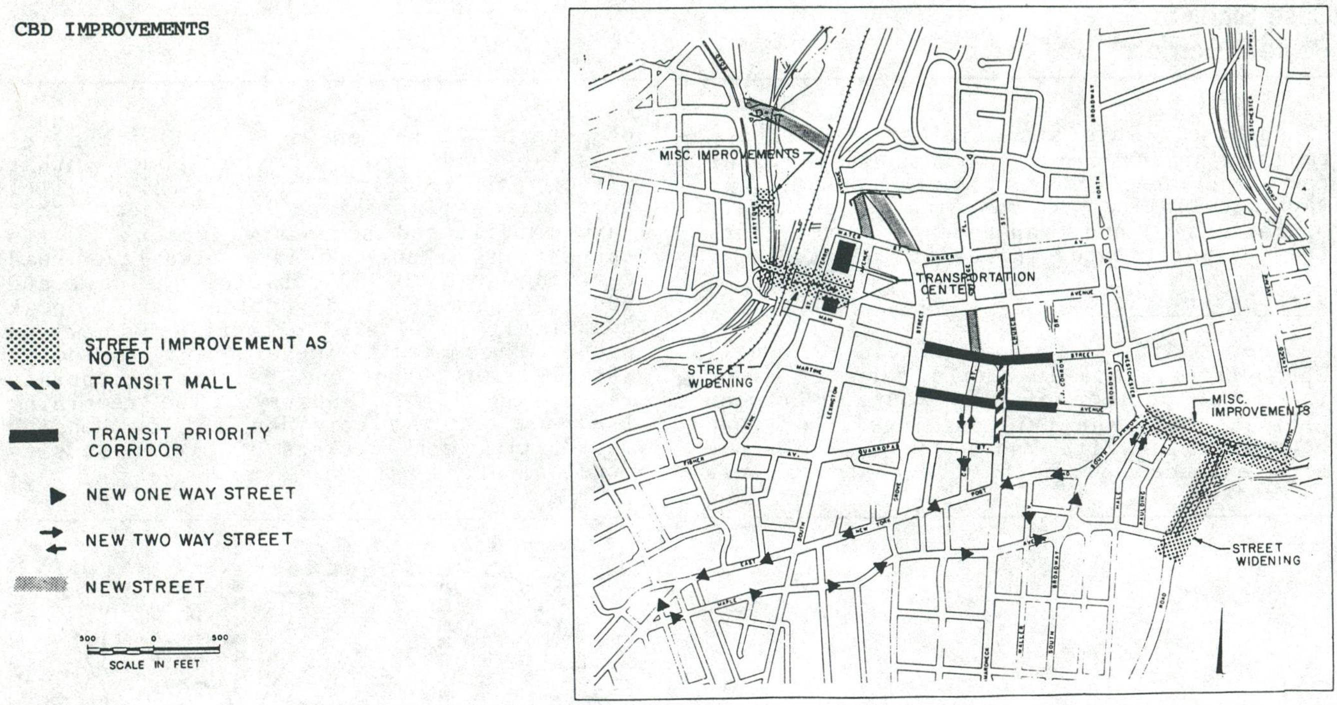
Improvements Planned by the City

- Centrally controlled traffic signal system
- Transportation center
- Street extensions, widenings and channelizations

Added Improvements

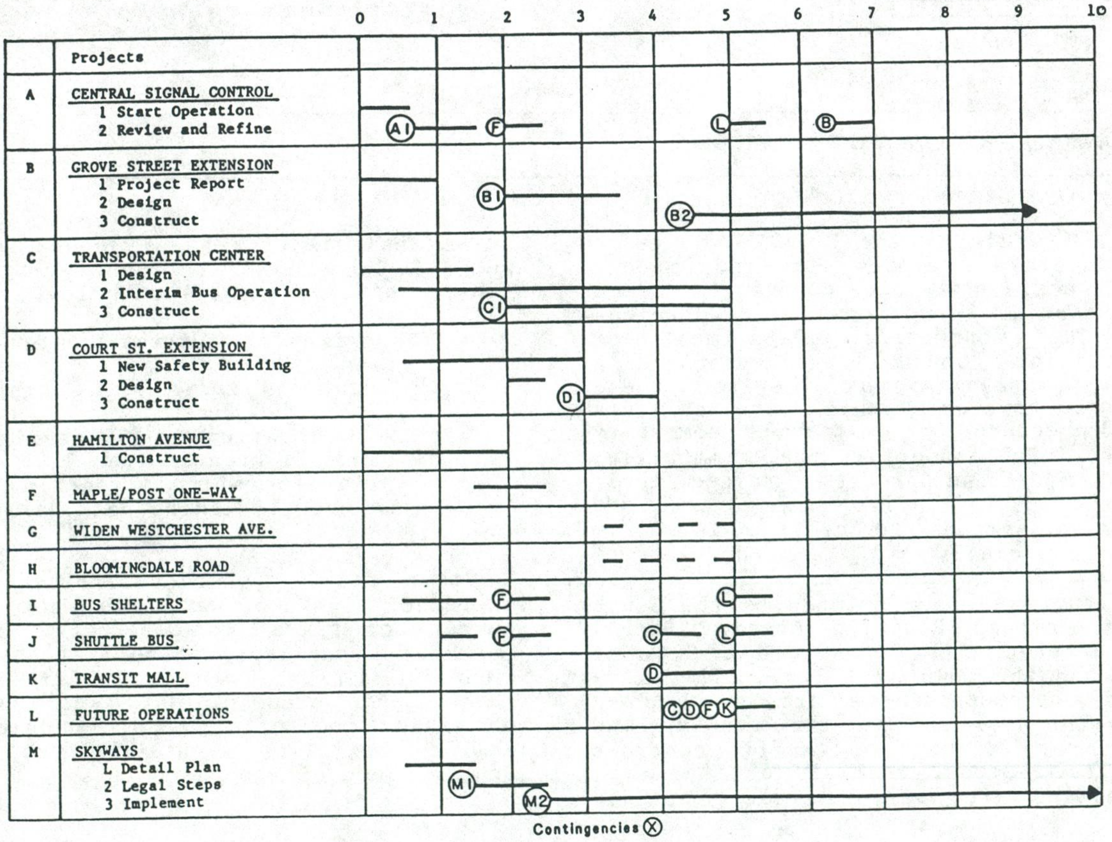
- New one-way streets
- Pedestrian and bus mall,
- Keyed to street extensions
- Skywalk system
- Shoppers shuttle bus service
- Transit service improvements
- Curb bus lanes
- Bus shelters
- "Quick stop" parking spaces
- Taxi stand relocation

CBD IMPROVEMENTS



A 3-stage sequence was developed for the recommended improvements, with priority given to those already in advanced planning or requiring minimal construction. Stage 1 (1982-1984) included improvements designed to alleviate major capacity restrictions and improve public transit. Stage 2 (1985-1987) actions included construction projects and related improvements to the downtown circulation system. Stage 3 (1988-1991) included completion of street extensions and the skywalk system. This ten year implementation schedule is shown below.

IMPROVEMENT SCHEDULE



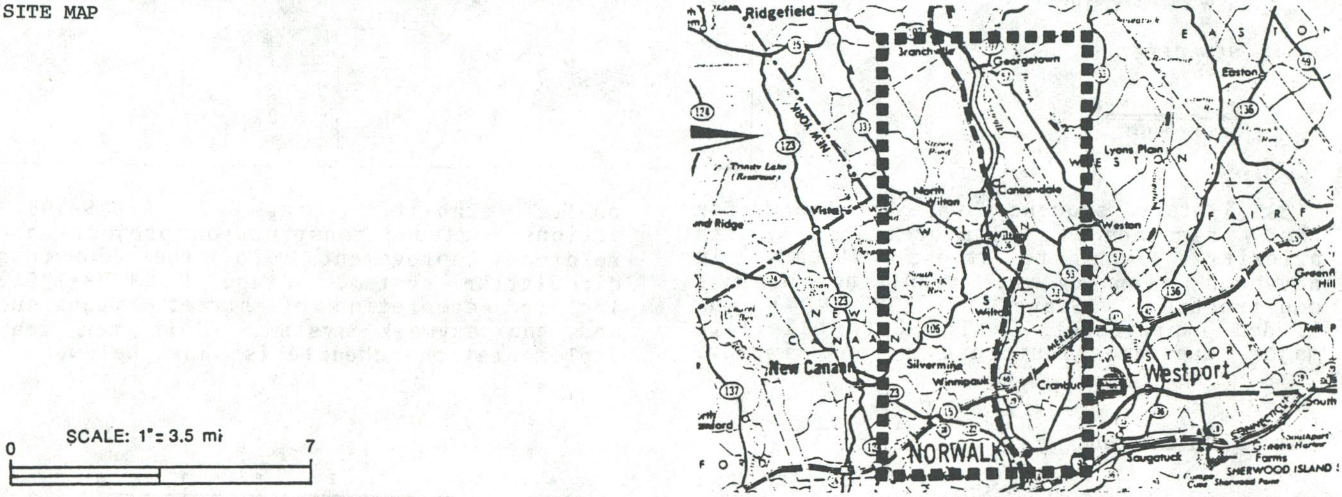
Case Study 5:
Route 7 Corridor

Purpose: This study illustrates short-range planning in a corridor where major new land developments are proposed, and the development of coordinated physical, operational, and management improvements to meet anticipated increases in travel.

Site Description

The site, in Fairfield County, Connecticut, is a 10.2-mile corridor along the lower portion of U.S. Route 7 between Norwalk and the Wilton/Ridgefield town boundary (see Site Map below). The study area extended one-half mile east and west of Route 7 to encompass (1) areas of existing and proposed development that affect its traffic flow and (2) parallel arterials and residential streets that have experienced secondary impacts of its congestion. Route 7 is a two-lane road carrying over 20,000 vehicles per day, and 800-1,000 in each direction during peak hours. It is flanked primarily by new and proposed commercial development including retail shops, shopping centers, corporate parks, and light industry. The remaining land use in the corridor is low density residential with pockets of higher density development.

SITE MAP



PHASE 1: ANALYZE PROBLEMS AND THEIR SETTING

The TSM study of the Route 7 Corridor was conducted in response to traffic congestion, accidents, and conflicts caused by substantial new commercial development. The Connecticut Department of Transportation (ConnDOT) had proposed a parallel expressway to alleviate these problems; however, this project was deferred because of costs and community concerns. Subsequently, the communities affected by these problems voiced their preference for traffic management and engineering actions to provide immediate relief, especially as land development continues.

The study was commissioned by the South Western Regional Planning Agency (SWRPA) in cooperation with ConnDOT, the City of Norwalk and the Town of Wilton. The findings and recommendations are based on a field reconnaissance of the roadway and its environs, surveys of traffic controls and traffic speeds, analysis of the data, and dialogue with various study participants.

An analysis of roadway geometrics found Route 7 between Norwalk and Danbury to be substandard, as summarized below:

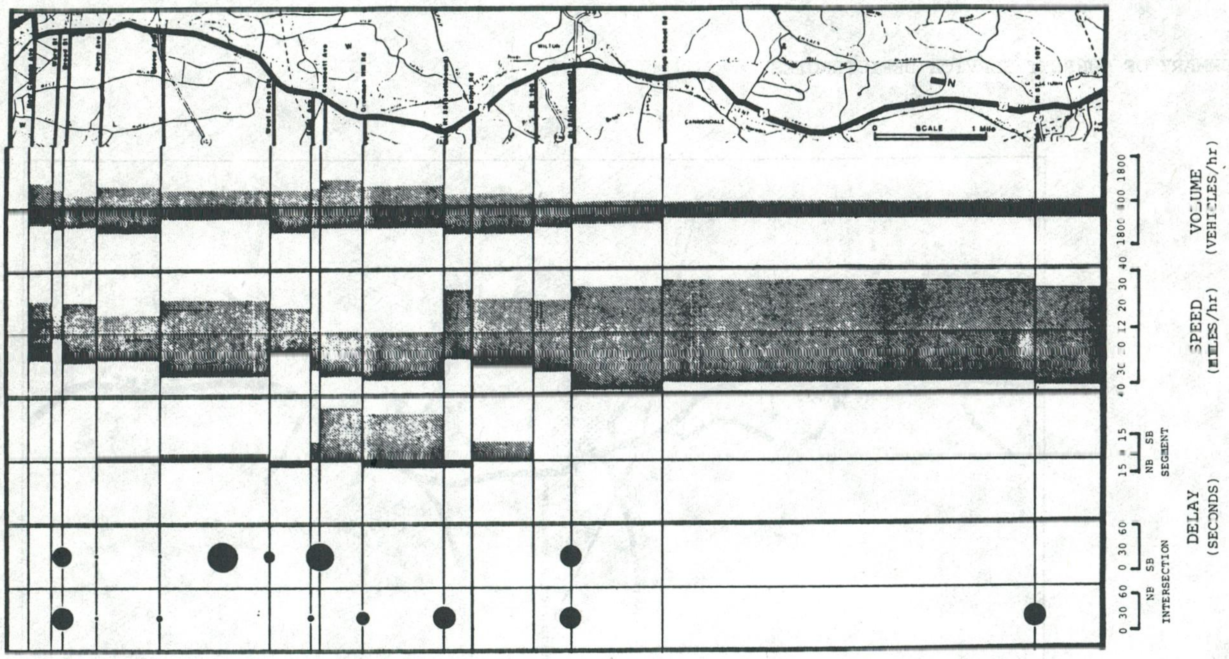
- 18 horizontal curves greater than 6 degrees
- 40 locations where sight distance is less than 400 feet
- only 1 location where passing sight distance is greater than 1700 feet.
- an at-grade railroad crossing through which over 15 trains pass daily.

Other roadway characteristics assessed included rights-of-way, pavement widths, numbers of travel lanes, traffic signals, pavement markings/channelizations, and curb cut densities. For traffic signalization, for example, data were collected on signal controller type, conduit availability, existing signal interconnection, and presence of loop detectors.

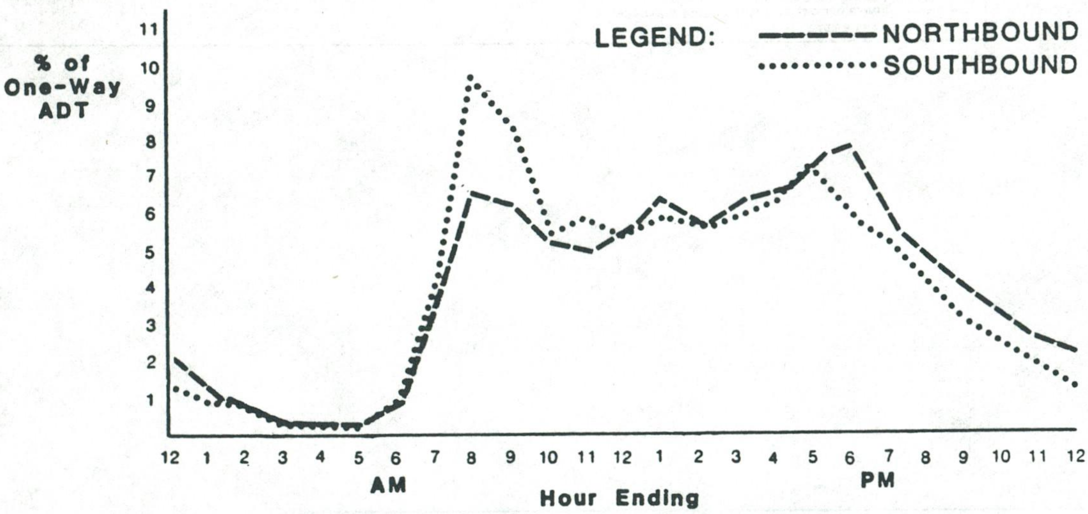
Data on traffic characteristics, speed and delay, and parking and pedestrian volumes also were collected. Vehicular volumes were compiled from ConnDOT traffic counts and then updated with counts from more recent traffic studies. Seasonal adjustments were made based on ConnDOT factors. Speed and delay studies for peak and midday periods determined average speeds on each route segment and delays experienced by motorists at major intersections. Strip maps, such as the one shown below, were then prepared to illustrate peak-hour and midday travel conditions along Route 7. In addition, the hourly distribution of vehicles was graphed, as shown below.

The amount of off-street parking was measured and pedestrian volumes and patterns were chronicled thoughout the day during the field reconnaissance. The availability of sidewalks for pedestrian use was also inventoried.

P.M. PEAK-HOUR TRAFFIC CHARACTERISTICS



HOURLY TRAFFIC DISTRIBUTION

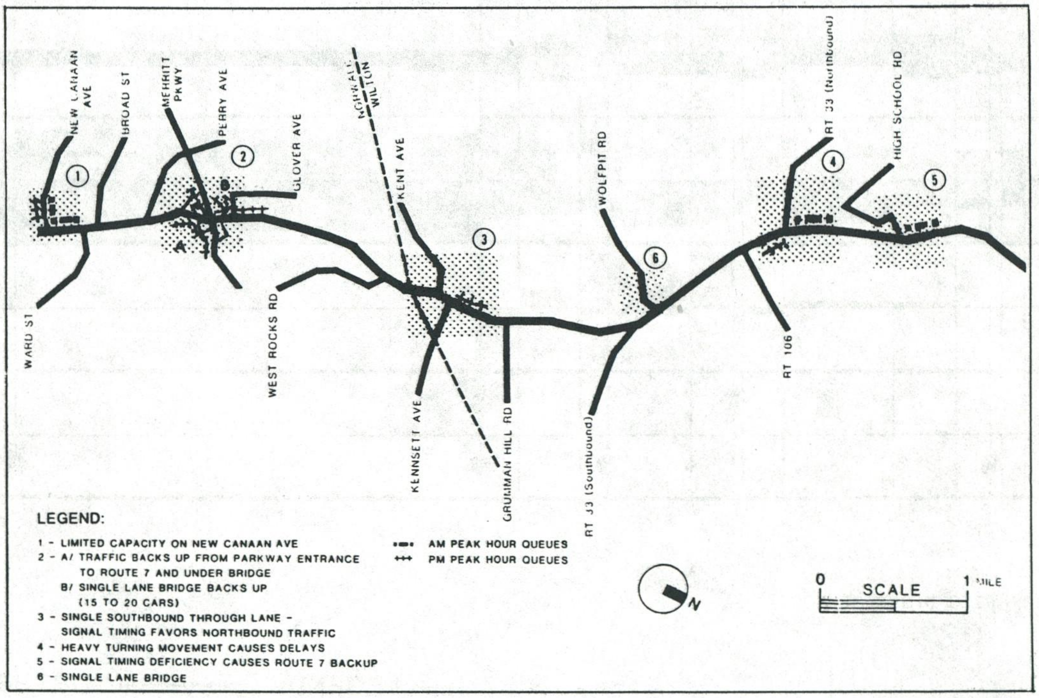


The analysis of the existing traffic operations described above indicated the following service deficiencies:

- Several roadway sections varied significantly in width and number of travel lanes.
- The volumes of traffic on Route 7 exceeded the 20,000 vehicle per day standard service capability of a basic two-lane roadway.
- Narrow, offset cross streets complicated signal timing and intersection geometry, increased left turn volumes along Route 7, and limited approach capacities.
- The proliferation of corporate parks and commercial developments resulted in short, sharp traffic peaks that substantially increased Route 7 flow during the peak traffic periods, a condition that would only be compounded by ongoing development.

The principal problem locations and locations of queues during peak periods were highlighted on a strip map, shown below.

SUMMARY OF CURRENT SERVICE DEFICIENCIES



In addition to existing problem areas, anticipated traffic conditions also were derived and assessed. The derivation of the anticipated traffic volumes 5 years into the future was based on the following steps:

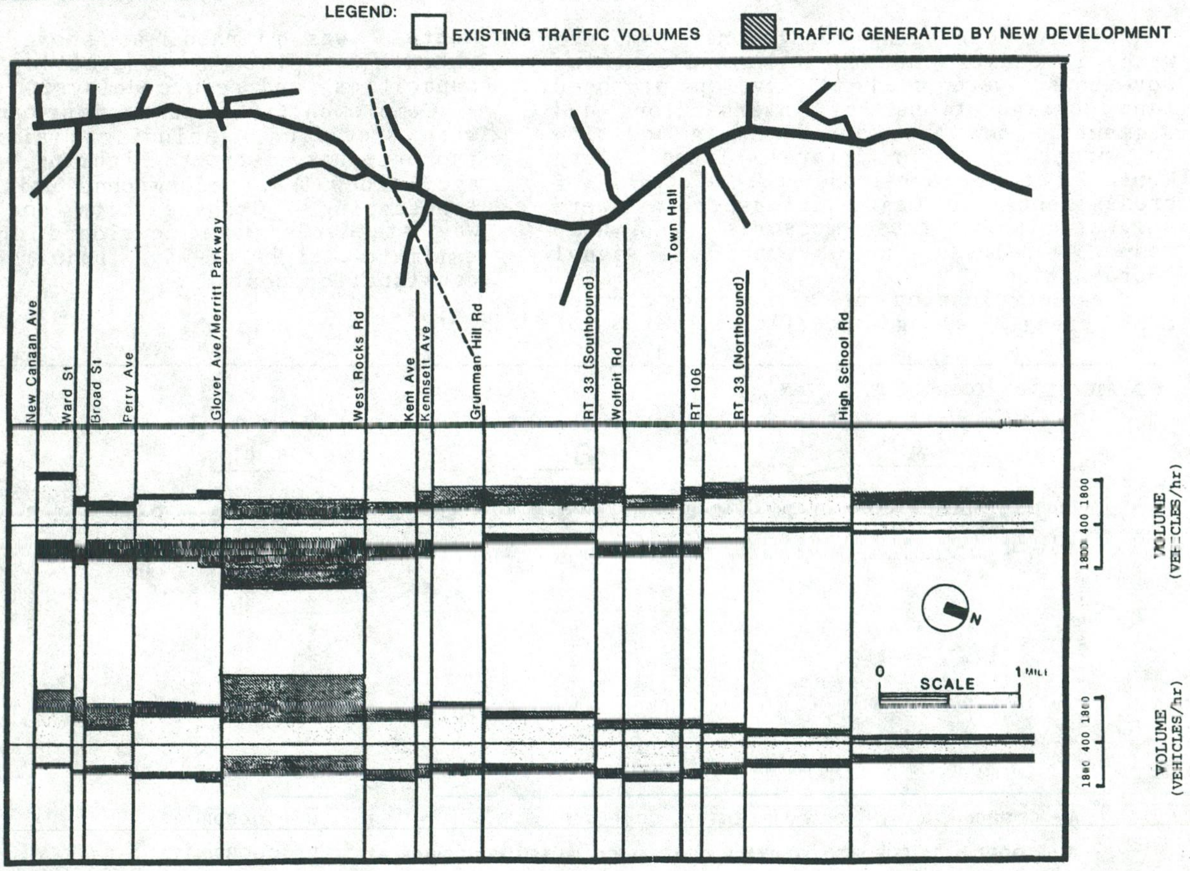
- Lists of "committed" residential and commercial developments were obtained zoning commissions and SWRPA; these included:
    - 760,000 sq ft of corporate office space
    - 635,000 sq ft of general office space
    - 115,000 sq of warehousing
    - 95,000 sq ft of industrial space
    - 32,000 sq ft of other commercial space
    - 300 hotel units
    - 350 condominium units
    - Norwalk Community College (3,300 students)
- Peak hour vehicle trips generated by these developments were estimated based on trip generation factors developed by the Institute of Transportation Engineers, ConnDot, and the Consultant Team.
- Trip origins were based on the results of an employee survey prepared for the SWRPA.
- Vehicle trips were then assigned based on the most direct routes between traveler origins and work sites.
- This additional development traffic was then superimposed upon existing peak hour corridor traffic flows to obtain composite future (1987) traffic volumes.

The results of this analysis were summarized in terms of additional numbers of vehicles entering and leaving the corridor during peak periods, as follows:

Direction	AM Peak Hour	PM Peak Hour
Inbound	2,680	710
Outbound	680	2,180

These trips, assigned to segments, were superimposed on existing traffic volumes, as shown below. The plots indicated that existing congestion and queueing problems would become more acute in the next 5 years as development continues. (For example, on certain sections, traffic volumes were forecast to more than triple the existing volumes.)

ANTICIPATED PEAK-HOUR TRAFFIC



PHASE 2: IDENTIFY AND SCREEN CANDIDATE SOLUTIONS

The initial intent of the study was to identify and design low cost management improvements to provide near-term relief to recurrent peak-hour congestion. However, a review of the problems described in Phase 1, especially that of forecast development along Route 7, warranted looking beyond management actions. Hence, three general categories of actions were considered: (1) do nothing, (2) limit or control development growth, and (3) expand the transport capacity.

The latter emerged as the preferred option of public officials and community groups. Accordingly, the following four groups of strategies to achieve this expansion were identified:

- Make minor adjustments of a "management" nature (e.g., turn lanes and signal improvements) to improve the traffic flow and the efficiency of the existing roadway.
- Expand public transit service and facilitate ridesharing and alternative work schedules to reduce the traffic volume.
- Develop a parallel route, such as the proposed Route 7 Expressway or a modified connector route to divert traffic as well as expand capacity.
- Widen and improve the existing Route 7 to improve traffic flow and add capacity.

In screening these candidate strategies, it was found that improved roadway management alone would not result in sufficient capacity increases to accommodate the forecast demand, nor would the development of an expressway provide immediate or near-term relief. While strategies such as transit expansion, ridesharing, and alternative work schedule programs were viewed as a desirable means to minimize the expected increase in traffic volumes, it was found that these actions, either alone or in conjunction with management actions, would not alleviate the congestion problems. Consequently, the only remaining solution that had the potential to accommodate the projected demand was to widen and otherwise improve the existing road system.

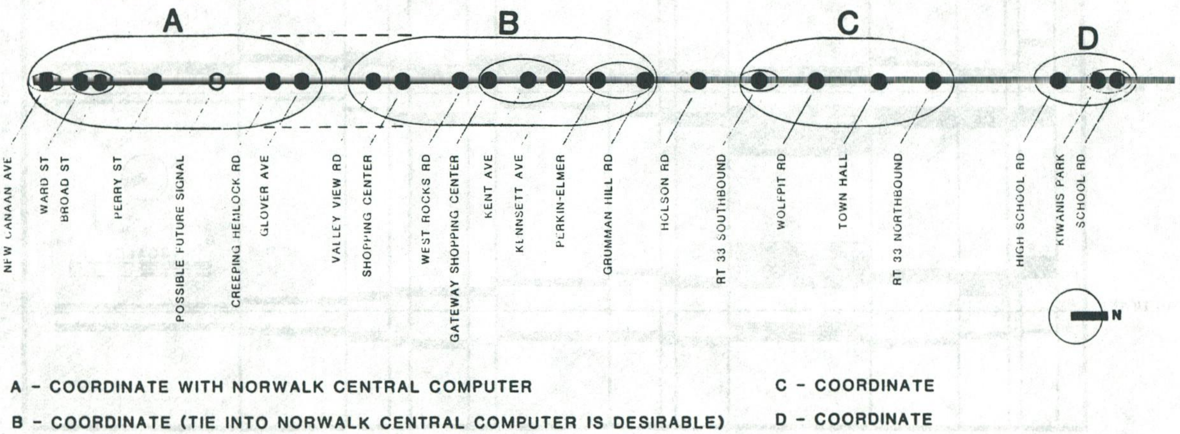
PHASE 3: ANALYZE, DESIGN AND EVALUATE SOLUTIONS

Existing operating conditions, combined with forecasts of through and turning movements, were used to develop proposed lane configurations for intersections and segments along the corridor. In addition to providing four travel lanes along Route 7, turn lanes and the widening of crossstreets at major intersections were suggested where these measures would help reduce delays and enhance signal coordination.

The coordination of signals on common cycle length along specific sections of Route 7 was planned, as shown before, to encourage platoon operation, increase capacities, and reduce delays.

Complementary roadway improvements also were specified, including drainage system improvements, street lighting, new signage, sidewalks, underground utilities, and landscaping. Cross-section and right-of-way standards were developed and used to estimate right-of-way requirements and construction costs.

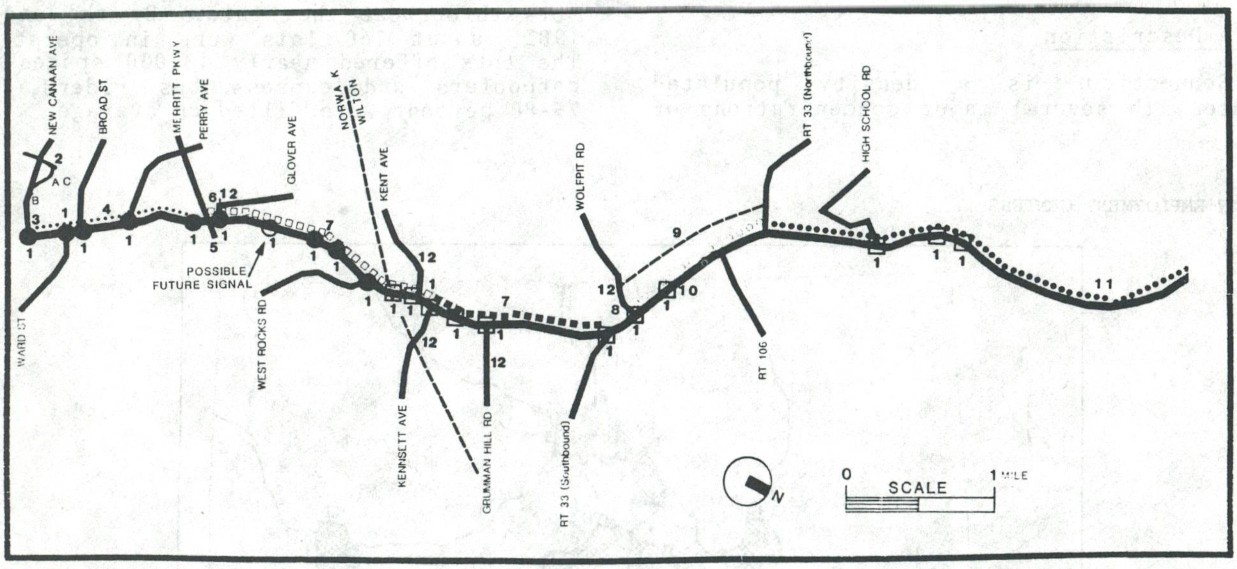
TRAFFIC SIGNAL COORDINATION PLAN



Specific roadway improvements were recommended to increase capacity, improve safety, and reduce delay. These included signal coordination, roadway widening with corollary improvements in intersection channelization, road geometry, and turning lanes, and expanded cross-street capacity. The locations of these improvements are shown below.

Supportive actions to encourage employers to adopt both ridesharing efforts and alternative work schedules and to encourage transit ridership also were identified. Collectively, it was estimated that these actions could reduce peak-hour car trips by as much as 25 percent in the peak direction, reducing volumes by approximately 400-500 vehicles.

SUMMARY OF ROADWAY IMPROVEMENTS



1 - COORDINATE TRAFFIC SIGNALS IN NORWALK ● AND WILTON ☐
2- ^A^PROVIDE A RIGHT TURN CONNECTOR FROM NEW CANAAN AVE TO ROUTE 7 EXPRESSWAY ^B^ WIDEN NEW CANAAN AVE TO 4 LANES
^C^PROVIDE A 3 LANE EXIT
3 - INCREASE TURNING RADIUS AT INTERSECTION
4 ....-PROVIDE FOUR TRAVEL LANES
5 - RECONSTRUCT ROUTE 7/MERRITT PARKWAY INTERCHANGE TO ELIMINATE WEAVING AND PROVIDE AN ACCELERATION LANE , PROHIBIT LEFT TURNS FROM THE WESTBOUND OFF RAMP - ULTIMATELY RECONSTRUCT THIS RAMP
6 - WIDEN GLOVER AVE BRIDGE
7 - PROVIDE FOUR THROUGH LANES PLUS A LEFT TURN LANE ▫▫▫▫▫▫▫▫▫ INITIALLY ▪▪▪▪▪▪▪ BY 1987
8 - BUILD A NEW BRIDGE ON WOLFPIT RD
9 ------ - BUILD A CONNECTOR WEST OF DANBURY BRANCH RAILROAD
10∘∘∘∘∘∘∘∘ - WIDEN TO THREE LANES (TWO THROUGH LANES PLUS LEFT TURN LANES): As an alternate to item 9, widen to 5 lanes
11••••••••• - PROVIDE TWO THROUGH LANES PLUS LEFT TURN LANES AT KEY INTERSECTIONS
12 - WIDEN CROSS STREET ON APPROACH TO ROUTE 7

The construction costs for the recommended improvements were estimated at $16,000,000, and it was suggested that these be shared by ConnDOT, the two local towns, and the developers. Recommended cost allocation for improvements was 50-50 between the state and developers for state roads and 50-50 between the towns and developers for local roads.

A 3-stage sequence, in which construction would progress from south to north, was recommended based on the following guidelines:

- Favor improvements that would alleviate major system capacity constraints and deficiencies (i.e., solve the current problems first).
- Favor improvements that would not merely transfer problems.
- Provide a reasonably even distribution of costs among the various program stages.

Detailed functional plans were prepared for key intersections as a preparation for final engineering and design.

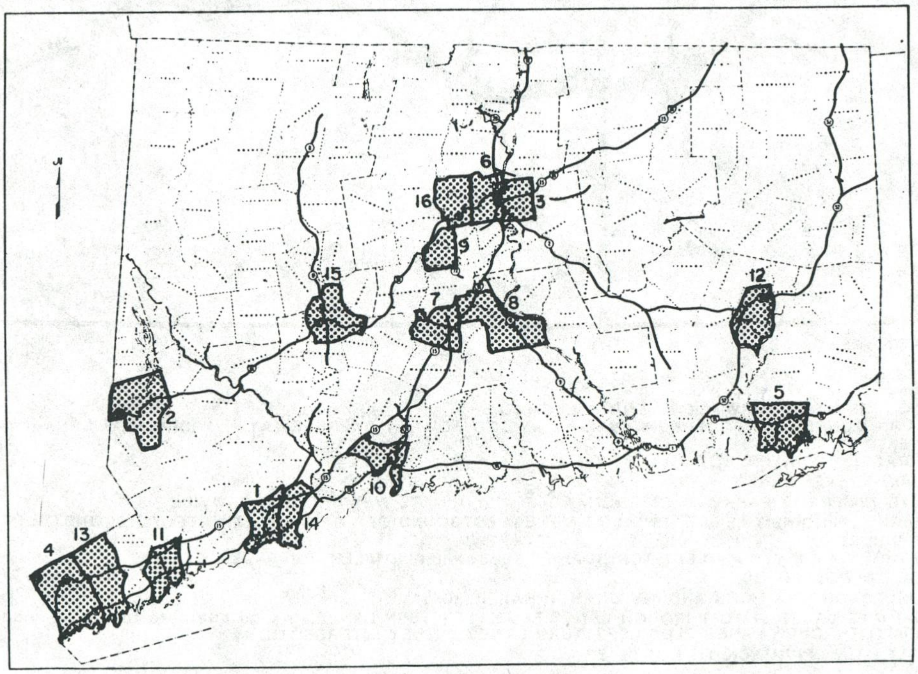
Case Study 6:
Connecticut Park and Ride Lots

Purpose: The case shows the operation of the planning framework at two levels. The first is a on-going statewide review and analysis to determine prime locations for park and ride lots, a process that has become increasingly refined using information on existing lots and users. The second level is the detailed siting and development of specific lots, for which procedures and guidelines also have been established.

Site Description

Connecticut is a density populated state with several major concentrations of employment (see map below). Its small size and good expressway network have lead to dispersed commuting patterns and long work trips. To accommodate this travel without further expanding facilities, to respond to air quality and energy conservation concerns, and to solve localized safety and traffic flow patterns caused by roadside parking, the Connecticut Department of Transportation (ConnDOT) has implemented a program of park and ride lots throughout the state. By the end of 1981, about 160 lots were in operation. The lots offered nearly 13,000 spaces for carpoolers and express bus riders, and 75-80 percent were filled on average.

URBAN EMPLOYMENT CENTERS



PHASE 1: ANALYZE PROBLEMS AND THEIR SETTING

Connecticut's Commuter Parking Program originated in 1969 with a study of all expressway interchanges in the state to determine the location, the amount, and the characteristics of commuter park-and-ride activities. The study, conducted by ConnDOT, was undertaken in response to the growing number of traffic hazards created by commuters who parked near expressway interchanges. A field inspection indicated that over 800 vehicles were parking, often illegally and haphazardly, at 83 different locations, notably at interchanges on the Meritt Parkway and the Connecticut Turnpike. To confirm the parkers were carpooling, and to obtain information on their destinations, ConnDOT placed prepaid postcards on parked cars at about 70 interchanges. The results indicated that most parkers were making a work trip, that their average trip distance was 36 miles, and that the primary destinations were Hartford, New Haven, and Stamford.

In the initial phases of the Commuter Parking Lot Program, the combination of state-owned land and a large number of cars parked beside roads near interchanges provided an easy means of selecting low-cost sites that would be well-used. For example, these criteria were used in 1979 to select four sites for a pilot program.

As the program has expanded, however, roadside parking has become a less reliable indicator of prospective lot patronage and, increasingly, private land must be used for new lots. To avoid investing $1200-$5000 apiece for spaces that will not be used, ConnDOT has developed a computerized screening technique for locating good site for new lots.

The method is based on a windshield postcard survey of lot users conducted in 1976. Plots of the responses (examples are shown on the following page) showed that most users parked within 10 minutes of their home, with very few driving than twenty minutes to reach a lot. The trip length from the lot to their workplace was more variable, but generally ranged between 15 and 50 minutes.

ConnDOT has developed a computer program that applies these trip length ranges to network-generated travel routes and census journey-to-work (or other O-D) data, and lists the number of potential lot users that pass each interchange on the way to a specific concentration of employment. Interchanges with many potential users are then inspected for feasible lot sites. Corridor studies also are conducted by comparing the potential use estimates for several major employment centers within commuting range of corridor residents.

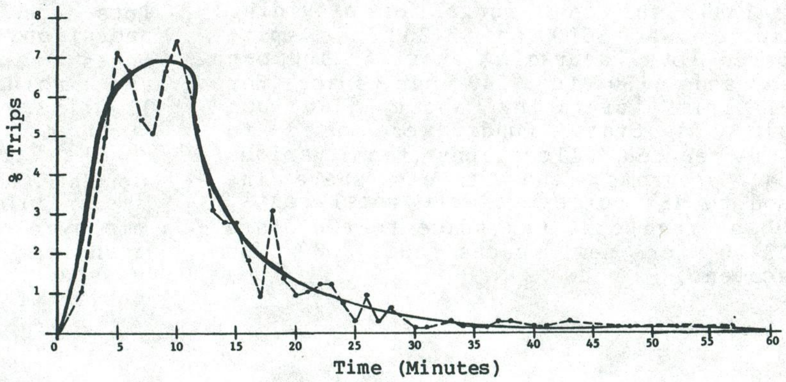
Suggestions by transit district, planning agency and other officials, as well as by citizens, also are used to identify prospective sites for park and ride lots.

The screening analysis is used to set program priorities for the coming year. Existing lots that are being used up to 80% of their capacity, and which show an increasing usage trend also are considered for expansion in preparing an annual program.

TRIP LENGTH DISTRIBUTIONS

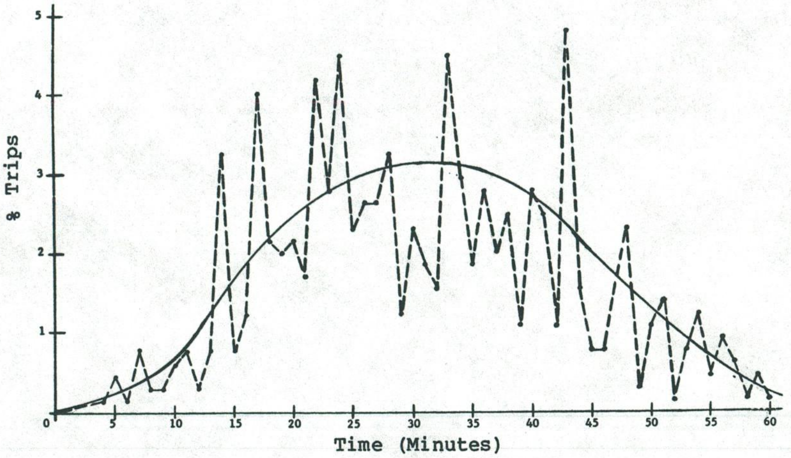
A. Home to Lot

(average time = 10.6 min.)



B. Lot to Workplace

(average time = 33.4 min.)



PHASE 3: DESIGN, ANALYZE, AND EVALUATE SOLUTIONS

During the early stages of the program, much emphasis was placed upon the speed with which each project could be completed. Consequently, in-house personnel (from the Office of Maintenance) were used extensively not only to develop signing plans, specifications, and estimates but also to build the lots. However, as the design and construction techniques for these facilities became more complex, the need for private land increased, and the number of projects grew, more detailed site planning and analysis became necessary. This phase now includes field review to identify specific sites, determination of construction feasibility, estimation of lot capacity, specification of amenities and cost estimation. Regional planning agencies and district, planning, design and construction offices of ConnDOT are involved in some of all of these activities.

Standard specifications for pavement markings, signing, lighting and sheltered waiting areas have been developed to simplify preliminary site planning and cost estimation.

PHASE 4: RECOMMEND AN ACTION PLAN

Once site selection and planning has been accomplished, ConnDOT's Office of Project Planning prepares a project recommendation form that is reviewed and processed by other departments in securing funding required for engineering, site acquisition and construction of a proposed lot. Site planning, engineering, acquisition and construction activities generally take 12 to 18 months to complete. In some cases, public hearings also are necessary.

In 1980, the cost range for providing new spaces was $500 to $2,200 per space for paved lots (averaging about $1,100 per space) and $150 to $240 per space for gravel lots (averaging about $180 per space). As State funds were used to replace reduced allocations from various Federal programs, the State's share increased to 45% percent of the total costs, so the average cost per space to the State was $420 for new spaces and $380 for replacement.

The cost of leasing spaces also has varied widely depending upon location. For example, spaces at church parking lots leased at $10 per space per year, while spaces at shopping centers leased at $22 per space per year. Operating expenses (not including lease costs) were estimated to be about $6.50 per space.

ConnDOT has prepared a standard licensing agreement for establishing lots when land is difficult to purchase or where lots are planned to support the trial operation of an express bus. The agreements are written for a two year period, and include provisions for maintenance, lighting, snow removal and liability insurance.

The lots are actively marketed by ConnDOT. State maps showing lot locations are regularly updated and distributed to employer carpooling offices and other agencies. Roadside signs, billboards and newspaper ads also are used to inform the public of the program.

References (Part III)

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Case Study #5

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Case Study #6

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