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Application of Analysis Tools to Evaluate the Travel Impacts of Highway Reconstruction with Emphasis on Microcomputer Applications

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The objective of this report is to provide guidance to highway agency officials on the use of available analysis tools to evaluate the travel impacts of major highway reconstruction projects. A process for travel impact evaluation is outlined. Guidelines on the selection of appropriate analysis tools are presented. Specific recommendations are made for three project scenarios (minor capacity reduction, partial closure total closure). Five categories of available analysis tools with potential application to the evaluation process are reviewed: network-based highway and transit planning models, quick-response estimation techniques, highway capacity analysis procedures, traffic simulation models, and traffic optimization models Corridor traffic management planning efforts in five cities (Pittsburgh; Boston, Philadelphia, Detroit, and Minneapolis) are also reviewed.

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Application of Analysis Tools to Evaluate the Travel Impacts of Highway Reconstruction with Emphasis on Microcomputer Applications

Texas Transportation Institute
The Texas A&M University System
College Station, TX 77843

June 1988

Final Report

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Prepared for

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Office of Planning
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1. INTRODUCTION

The United States is facing an extended period in which major highway reconstruction projects will be undertaken in urban areas throughout the country. The problem of reconstructing highways while accommodating the large traffic volumes that use them is a formidable one. The Federal Highway Administration (FHWA), in recognition of the significance of the problem, sponsored a National Conference on Corridor Traffic Management for Major Highway Reconstruction in 1986. The Conference Proceedings (1) stated:

> The era of major reconstruction projects is just beginning. Because of the age of much of the urban highway system, and the mounting volume of traffic that major routes must carry, many cities in this country are going to be facing very serious reconstruction problems. The problem is not going to go away; it will be around for many years and must be dealt with.

BACKGROUND

Roadway space is a scarce resource that must be allocated between the required reconstruction activities and the motorists. Reconstruction activities could be expedited by closing as much of the highway as possible. But in many cases, the rest of the urban transportation network could not accommodate the traffic that would be diverted away from the highway. In planning a major highway reconstruction project, an acceptable balance must be reached between the following objectives:

- Maximizing the safety and efficiency of the reconstruction activity
- Minimizing the adverse impacts on motorists and affected communities

Highway agency officials must be able to estimate the travel impacts of alternative reconstruction and traffic management strategies in order to determine the proper allocation of roadway space. At present, little information exists about appropriate analysis tools to evaluate these impacts. Some states have developed analysis procedures; however, the application of these procedures has been limited, and little guidance exists on their use. A number of successful corridor traffic management plans have been implemented. The lessons learned from these experiences should be shared with officials from other agencies facing the rebuilding of major highway facilities.

SCOPE AND OBJECTIVE

The objective of this report is to provide guidance to highway agency officials on the use of available analysis tools to evaluate the travel impacts of major highway reconstruction projects. The term “major” is intended to imply that:

- o The highway being reconstructed carries high traffic volumes
- o The project will affect an extended length of roadway for a significant period of time
- o The adverse travel impacts resulting from the project are potentially severe

The report provides:

- o A travel impact evaluation process for major highway reconstruction projects
- o Guidelines on the selection of appropriate analysis tools
- o Reviews of available analysis tools which have potential application
- o Reviews of corridor traffic management planning efforts for five major highway reconstruction projects

The scope of this report--the application of available analysis tools for travel impact evaluation--is only a part of the corridor traffic management planning process. The major tasks in developing an effective corridor management program are outlined in Table 1. The role of the travel impact evaluation process is to produce the information that decision makers need in order to select among alternative transportation management plans.

Available Analysis Tools

Available analysis tools with potential application to the reconstruction project travel impact evaluation process are grouped into five categories:

- o Network-based highway and transit planning models
- o Quick-response estimation techniques
- o Highway capacity analysis procedures
- o Traffic simulation models
- o Traffic optimization models

TABLE 1. CHECKLIST OF TASKS IN DEVELOPING A CORRIDOR MANAGEMENT PROGRAM FOR A MAJOR HIGHWAY RECONSTRUCTION PROJECT

I. DEVELOP TRANSPORTATION MANAGEMENT PLAN

- * A. Identify and quantify the problem
- * B. Identify the corridor
- * C. Inventory the corridor system
- D. Identify key opinion makers
- E. Develop support for transportation management concept
- F. Establish transportation management team and other committees
- * G. Identify goals and constraints
- * H. Identify possible mitigation measures
- * I. Quantify contributions and estimated costs of mitigation measures
- J. Identify funding sources and amounts
- K. Select traffic mitigation plan and schedule
- L. “Sell” the traffic management plan to support and funding agencies
- M. Include traffic management plan provisions in contract documents

II. PREPARE TO CARRY OUT PLAN

- A. Prepare public awareness campaign
- B. Establish implementation team
- C. Perform necessary “off-project” work identified above
- D. Insure adequate staffing for plan implementation
- E. Perform necessary dry runs and refine plan as needed
- F. Publicize and market traffic management plan

III. CARRY OUT AND OPERATE PLAN

- A. Start construction
- B. Begin ongoing transportation monitoring program
- C. Continue weekly transportation management team meetings
- D. Maintain incident management efforts
- E. Maintain media briefings

IV. POST-CONSTRUCTION ACTIVITIES

- A. Continue transportation management team for ongoing customer service
- B. Hold separate post-construction meeting to discuss plan
- C. Evaluate contractor for pre-qualification ratings for future jobs
- D. Evaluate and revise checklist for future construction projects

*Scope of the travel impact evaluation process.

Source: Transportation Management for Major Hiahway Reconstruction. Special Report 212. Washington, DC: Transportation Research Board, 1987.

The analysis tools in each category that are reviewed in this report are listed in Table 2. Only a sample of the analysis tools available were reviewed. The Microcomputers in Transportation Software and Source Book (2) provides a more extensive list of available microcomputer-based analysis tools. The selection of particular tools for review does not indicate an endorsement of those tools.

Each category of analysis tools has specific applications. Network-based highway and transit planning models perform travel demand modeling functions (i.e., trip generation, trip distribution, mode split, and traffic assignment) using a link-node representation of the highway and transit networks in an urban area. Quick-response estimation techniques perform some or all of the same travel demand modeling functions using simplified, non-network-based analyses that are less time, labor, and data intensive than network-based models. Highway capacity analysis procedures translate roadway, traffic, and operational control conditions into estimates of capacity, level of service, and other operational measures of effectiveness (MOEs). Traffic simulation models are able to account for the time-varying nature of traffic flows and the complex interactions among highway geometric elements in estimating operational and/or economic MOEs as a function of roadway, traffic, and operational-control conditions. Traffic optimization models are used to develop optimal signal phasing and timing plans for isolated signalized intersections, arterial streets, or signal networks.

Summaries of a sample of available analysis tools in each category are provided in Appendix A. More detailed reviews of the tools are presented in Appendix B.

It should be emphasized that current knowledge is limited on how motorists adjust their travel patterns in response to a major highway reconstruction project. Furthermore, there have been few, if any, reconstruction-related applications of many of the tools reviewed in this report. Therefore, it is difficult to make definitive statements on how accurately the analysis tools would perform in a reconstruction context. Many of the applications that have been documented are summarized in this report. However, it is important that the experiences gained and lessons learned from major reconstruction projects continue to be documented and shared with highway agency officials throughout the country so that planning procedures and analysis tools can be improved.

TABLE 2. ANALYSIS TOOLS REVIEWED IN THIS REPORT

ANALYSIS TOOL	SEE REVIEW ON PAGE
NETWORK-BASED HIGHWAY AND TRANSIT PLANNING MODELS	B-2
QUICK-RESPONSE ESTIMATION TECHNIQUES	
NCHRP 187 Manual Methods	B-8
NCHRP 255 Traffic Assignment Refinement Techniques	B-13
LINKOD	B-19
TRIPS	B-l 9
MODE CHOICE	B-23
RTD Pivot Point Logit Model	B-23
HIGHWAY CAPACITY ANALYSIS PROCEDURES	
1985 Highway Capacity Manual/ FHWA Highway Capacity Software	B-26
TRAFFIC SIMULATION MODELS	
QUEWZ	B-33
FREWAY	B-33
DELAY	B-33
FREQ	B-39
TRAFLO	B-39
INTRAS	B-39
NETSIM	B-48
PASSER-IV	B-52
TRAFFIC OPTIMIZATION MODELS	
SOAP	B-57
TRANSYT-7F	B-57
SIGOP **III**	B-57
PASSER II-87	B-57
MAXBAND 86	B-57

NOTE: This list is not intended to be all inclusive. Existing analysis tools are frequently modified and updated, and new tools are continually being developed.

Previous Experiences with Corridor Traffic Management Planning

Major reconstruction projects have been completed or are currently underway on a number of major urban freeways throughout the United States. There are many valuable lessons to be learned from those experiences. This report summarizes the experiences from five major projects, listed below in chronological order:

- I-376, Penn-Lincoln Parkway East, in Pittsburgh
- I-93, Southeast Expressway, in Boston
- I-76, Schuylkill Expressway, in Philadelphia
- US-IO, John C. Lodge Freeway, in Detroit
- I-394 in Minneapolis

Each project had the potential for seriously disrupting traffic flow. The responsible agencies took considerable effort to evaluate the potential impacts and to develop strategies to mitigate those impacts. The approaches taken to evaluate the potential impacts included the use of regional transportation models, quick-response estimation techniques, highway capacity analysis, and manual traffic assignments.

In each case, the question was what the nature and magnitude of the impacts would be. In Pittsburgh, quick-response estimation techniques were used in the early stages of the planning process to evaluate corridor-wide impacts. In Boston, the results from a recent origin-destination survey, along with capacity analysis and manual traffic assignments, were used to evaluate travel impacts. In Philadelphia, an origin-destination study was conducted in the corridor; the results from the study, coupled with manual traffic assignments, formed the basis for the travel impact evaluation. In Detroit, officials made use of the regional transportation model to perform traffic assignment analyses for the alternative traffic management strategies that were being considered. In Minneapolis, planning for the reconstruction period was performed as part of a larger planning effort for developing a long-range Transportation Systems Management (TSM) plan for the I-394 corridor.

The traffic management strategies that resulted from the planning effort also varied. In Pittsburgh, work was performed in one direction of the four-lane Parkway East while two-way traffic was maintained in the other direction. An extensive package of TSM-type improvements on alternative routes and modes was implemented to mitigate the adverse travel impacts of the capacity reductions on the Parkway.

In Boston, the six-lane Southeast Expressway was divided into four two- lane segments (with shoulders used as temporary lanes) and the segments were allocated as follows: one segment at a time was reconstructed, two segments were dedicated to directional traffic flow, and one segment was reversible for peak direction through traffic during peak periods. An extensive package of TSM improvements on alternative routes and modes was implemented to provide the maximum number of travel alternatives to Expressway users.

In Philadelphia, the reconstruction of the Schuylkill Expressway was divided into three phases. Throughout the reconstruction zone, two lanes of the Expressway, which varied in cross section from four to eight lanes, were closed. In the four-lane segments, this meant that two-way traffic operated on one directional roadway while the other roadway was reconstructed. Most of the entrance ramps in the reconstruction zone were closed in order to control local traffic demand. In addition, TSM-type improvements were made to alternative routes and modes to accommodate diverted local traffic.

In Detroit, one direction of the six-lane Lodge Freeway was closed at a time, and all traffic in that direction was diverted to alternative routes. Normal traffic operations were maintained in the open direction. The unused capacity that was available on four primary alternative routes was almost sufficient to accommodate the diverted traffic, and therefore, only minor improvements were made to alternative routes and modes.

In Minneapolis, only minor capacity reductions were made on US 12--the route being upgraded to I-394--and an interim reversible HOV lane was provided in the median since only limited unused capacity was available on alternative routes in the corridor.

The experiences from the five projects reviewed demonstrate that major urban freeway reconstruction can be conducted without intolerable disruptions in corridor traffic flow. The planning approaches for each project were successful in that they provided the information that led to effective corridor traffic management plans. The traffic management and impact mitigation strategies, the latent capacity in the corridor, and the ingenuity of motorists in adjusting their travel patterns all contributed to the fact that the regional transportation networks were able to accommodate the capacity reductions on the highway being reconstructed with less congestion and delay than project planners had predicted.

More detailed reviews of the experiences at the five projects are presented in Appendix C.

ORGANIZATION AND CONTENTS OF THE REPORT

The following sections of the report are organized to assist highway agency officials in:

- Determining the types of analyses that might be required to evaluate the travel impacts of a major highway reconstruction project
- Identifying appropriate analysis tools for conducting these evaluations

Section 2 of the report presents a travel impact evaluation process for major highway reconstruction projects. The process is an organized framework of steps that are typically followed in evaluating travel impacts. The evaluation process was designed to assist officials in determining the types of travel impact evaluations that are required and in identifying the general categories of analysis tools that could be used in each step of the evaluation.

Section 3 presents guidelines on the selection of analysis tools that would be appropriate for a particular reconstruction project. The guidelines identify the key factors that should be considered in selecting the analysis tools to use for a particular project.

Section 4 summarizes the recommendations of the report.

Appendix A provides a one-page summary of each analysis tool that was reviewed. The summaries discuss the analysis capabilities, data requirements, output, computer needs, and availability of the tools.

Appendix B provides more detailed reviews of the analysis tools. The reviews discuss each tool's application and purpose, use, limitations, data requirements, advantages and disadvantages, success at forecasting travel during actual reconstruction, and appropriateness for reconstruction project travel impact evaluation.

Appendix C contains detailed reviews of the planning efforts for five major reconstruction projects. The reviews summarize the planning efforts undertaken, the traffic management strategies employed, and the actual travel impacts observed. The reviews highlight the experiences gained from these projects.

The report is structured so that the reader can gain insights from the main body of the report about the steps in the evaluation process and the types of analysis tools that may be appropriate for a particular reconstruction project. The reader may then refer to Appendices A and B for more detailed information about the types of analysis tools that are of particular interest and to Appendix C for insights into the experience gained and lessons learned from five actual projects.

2. RECONSTRUCTION PROJECT TRAVEL IMPACT EVALUATION PROCESS

Each highway reconstruction project is different--with a unique set of conditions and constraints that requires individualized analyses and customized solutions. However, many of the factors that should be considered in evaluating the travel impacts of highway reconstruction are common to most projects. The travel impacts are changes in travel patterns (particularly traffic diversion to alternative routes) and increases in travel times throughout the affected corridor. The affected corridor consists of the highway being reconstructed as well as alternative routes and modes of travel.

This section of the report outlines a process for evaluating the travel impacts resulting from a major highway reconstruction project and identifies the types of analysis tools that might be useful in the process. The travel impact evaluation process is a logical sequence of steps typically followed in estimating the travel impacts associated with alternative traffic management strategies for major highway reconstruction projects. A flow chart of the process is presented in Figure 1. The outputs from the process are pertinent MOEs that would be useful to highway agency officials in selecting among traffic-handling options and in finalizing a traffic management plan. The development of the process was based on the reviews of the planning efforts for the five projects summarized in Appendix C as well as on insights from the planning procedures recommended by Abrams and Wang (3) Neveu and Maynus (4) Anderson et al. (5) and the Texas Transportation Institute (6).

As Figure 1 illustrates, the process begins with an inventory of the affected corridor and the identification of the traffic-handling options to be evaluated. These steps are interrelated. Knowledge of conditions in the corridor (particularly the availability of unused capacity on alternative routes) influences the selection of viable traffic-handling options. On the other hand, the types of traffic-handling options that are being considered influence the scope of the inventory. For example, if significant reductions in capacity are being considered, then all routes that are likely to be affected should be inventoried; but if the policy of the highway agency is to maintain adequate reconstruction zone capacity for existing traffic, then the inventory might be restricted to the highway being reconstructed.

A major determinant of the severity of the travel impacts is the magnitude of the reduction in capacity on the highway being reconstructed. Therefore, the first step in evaluating a particular traffic-handling option is to estimate the capacity of the reconstruction zone. If the reconstruction zone has adequate capacity to accommodate

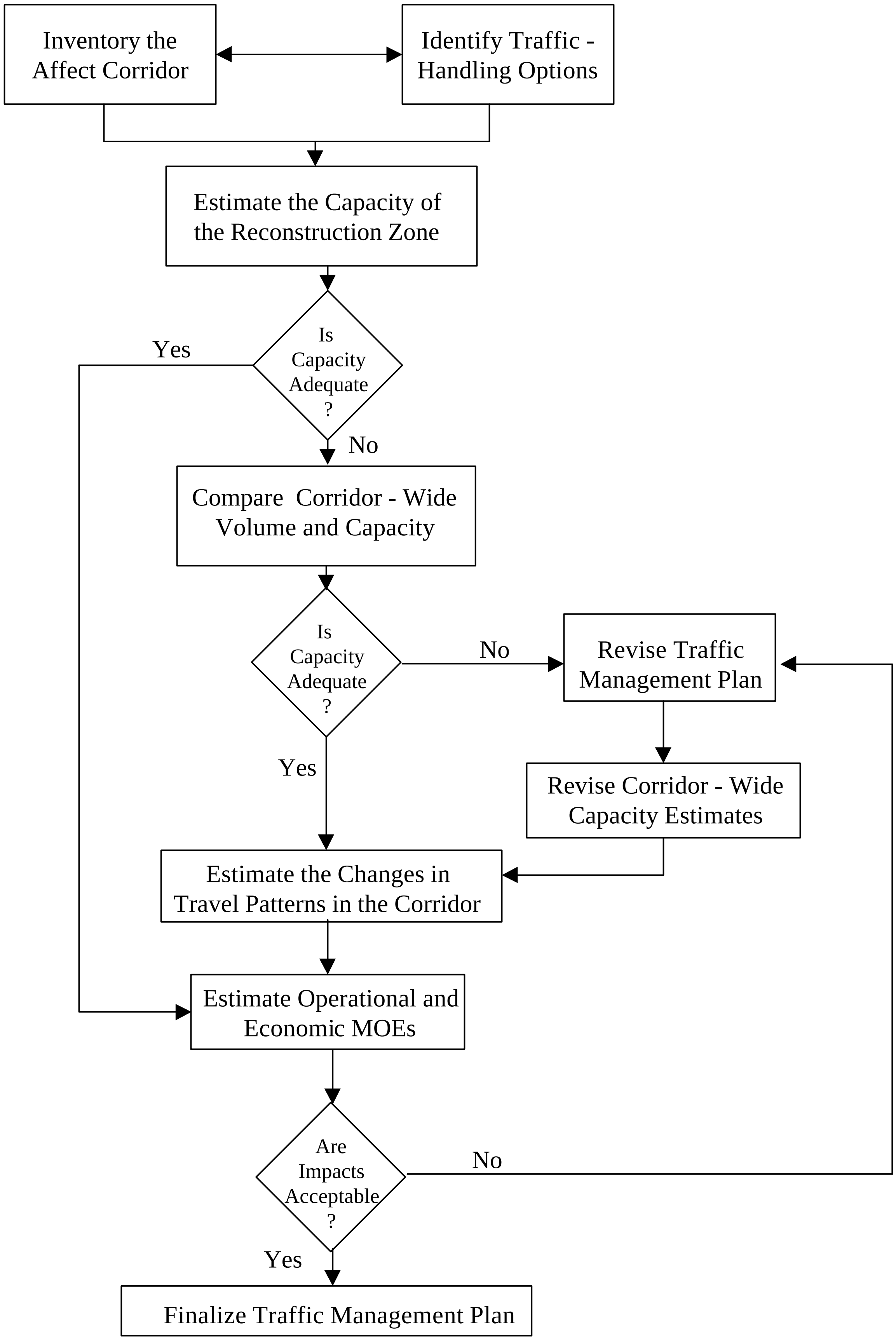

Figure 1: Flow Chart of Reconstruction Project Travel Impact Evaluation Process

normal traffic volumes (i.e., what the traffic volumes would be without the reconstruction project) at an acceptable level of service, then the scope of the evaluation may be restricted to the highway being reconstructed. In this case, the travel impact evaluation is straightforward and may proceed directly to the estimation of operational and economic MOEs for comparison with other alternatives that are being considered.

If the capacity of the reconstruction zone is not adequate, then some traffic would be forced to divert to alternative routes and modes. The travel impacts would extend beyond the highway being reconstructed, and therefore, the scope of the evaluation should be corridor-wide. For a corridor-wide evaluation, the next step would be to compare corridor-wide traffic volume and capacity. If the total capacity of all routes and modes in the corridor appears sufficient to accommodate normal corridor-wide traffic volumes across key screenlines at an acceptable level of service, then the evaluation may proceed with estimating the changes in travel patterns in the corridor. However, if the existing capacity in the corridor is inadequate, then it may be necessary to refine the traffic management plan to incorporate special impact mitigation strategies. In this case, the corridor-wide capacity estimates should be revised to account for the selected impact mitigation strategies.

A key step in a corridor-wide evaluation is estimating the changes in travel patterns in the corridor. The experiences from the five projects reviewed in this report suggest that the changes are most likely to be a reallocation of traffic among alternative routes and modes in the corridor.

The next evaluation step is to translate the predicted changes in travel patterns in the corridor into operational and economic MOEs. Operational MOEs, including travel times and average speeds, are needed to determine whether the travel impacts for a particular traffic management plan are acceptable as well as to compare alternative plans. Economic MOEs, particularly road user costs, are needed to compare the costs and benefits of alternative plans. If the travel impacts associated with a particular plan are deemed unacceptable, then the plan should be either refined or eliminated from further consideration. If the plan is refined, it should be re-evaluated. The process continues until decision makers have all the information they require to select a final plan.

The following paragraphs provide a more detailed discussion of the steps in the impact evaluation process.

INVENTORY THE AFFECTED CORRIDOR

The first step in the travel impact evaluation process is to inventory the affected corridor. The inventory can be broken into four parts:

- Define the boundaries of the affected corridor
- Inventory the existing transportation facilities and services in the corridor
- Inventory the current usage in the corridor
- Estimate operational MOEs for existing conditions

Knowledge of existing transportation facilities and services and traffic conditions influences the development of alternative traffic management strategies. The existing traffic conditions represent the base condition against which the traffic patterns and travel impacts of alternative traffic management plans are compared. Thus, a thorough and accurate inventory is vital to the establishment of reasonable goals, the identification of viable traffic-handling options, the accuracy of travel impact estimates, and the soundness of the decisions made concerning the reconstruction project.

Define the Boundaries of the Affected Corridor

The boundaries of the affected corridor define the scope of the evaluation. The extent of the region affected by a reconstruction project depends primarily upon:

- The severity of the capacity reductions on the highway being reconstructed
- The availability of unused capacity on alternative routes and modes
- The opportunities to increase the capacity of alternative routes and modes

The scope of the evaluation should include all routes likely to experience significant changes in travel patterns during reconstruction.

Inventory the Existing Transportation Facilities and Services in the Corridor

The transportation facilities and services that should be inventoried include the following:

- The highway being reconstructed

- The major alternative highway routes for diverted traffic
- Other surface streets that may also be impacted
- Existing bus, rail transit, and commuter boat routes and terminals
- High-occupancy vehicle (HOV) services and facilities including carpool/vanpool programs and park-and-ride lots

The inventory of the transportation system in the affected corridor is a data collection effort that defines the capacity and other important link characteristics of the existing highway and transit networks. The capacity of the links in each network is of primary interest. Highway capacity analysis procedures may be used to translate link characteristics into capacity estimates if capacity estimates are not available from previous studies.

Link characteristics that either influence capacity or limit the opportunities for improvements on alternative routes should be identified. Important link characteristics include:

- Roadway cross section (facility type, number of travel lanes, lane and shoulder widths, and on-street parking)
- Restrictions on turning movements or on use by trucks (and whether they are imposed for operational, geometric, or structural reasons)
- Presence of traffic signals and other controls (location of signal- or stop-controlled intersections; type of control; and signal phasing, timing, and coordination)

Inventory the Current Usage in the Corridor

The inventory of the current usage in the affected corridor is primarily a data collection effort that should define the volume and character of traffic using the existing highway network, and the ridership of the existing transit networks. Important usage data for the highway network include:

- Directional traffic volumes (daily and hourly)
- Traffic composition (by vehicle type)
- Auto occupancy (on both the highway being reconstructed and the alternative routes)
- Origins and destinations of current users of the highway being reconstructed

The data collection procedures for the first three items listed above are straightforward. However, it may be more difficult to identify the origins and destinations of current users of the highway being reconstructed. An origin-destination trip table is necessary in order to perform a corridor-wide evaluation. Table 3 identifies the alternative ways to obtain a trip table. If an origin-destination trip table is not available from a regional transportation model or a previous study, then considerable effort would be required to obtain the desired information.

Estimate Operational MOEs for Existing Conditions

The inventory should also estimate operational MOEs, including average travel times and speeds, which would define the base condition against which the travel impacts of the reconstruction project would be compared. These MOEs should be obtained through travel time studies in the corridor. In lieu of field studies, travel times could be estimated for comparative purposes using (1) the traffic assignment component of network-based planning models, or (2) traffic simulation models. However, some actual travel time data should be collected to calibrate the models and to validate their estimates of travel times.

IDENTIFY TRAFFIC-HANDLING OPTIONS

In this step, it is assumed that decision makers select one or more basic traffic-handling options that they would like the analyst to evaluate. The travel impact evaluation process as illustrated in Figure 1 is structured to evaluate one traffic-handling strategy at a time. Therefore, if several alternatives are to be evaluated, the process would be repeated for each alternative in turn. At each decision point, the decision maker should determine how to proceed, based upon the information supplied by the analyst.

Traffic-handling options may be characterized by the magnitude of the reduction in capacity on the highway being reconstructed. The individual strategies represent different allocations of roadway space between the contractor and the motorists. Traffic-handling options may be grouped into three general categories:

- Minor capacity reductions--the narrowing of lane and/or shoulder widths in order to maintain the same number of lanes on the highway being reconstructed, at least during peak periods

- Partial closure--the closure of some, but not all, lanes in one or both directions of the highway being reconstructed

TABLE 3. ALTERNATIVE WAYS TO OBTAIN AN ORIGIN-DESTINATION TRIP TABLE

1. USE AN EXISTING TRIP TABLE:

   a. Use an up-to-date trip table from a validated regional transportation model, or

   b. Refine and update a trip table from a previous study using a quick-response estimation technique (TRIPS or LINKOD).

2. CREATE A NEW TRIP TABLE:

   a. Perform an origin-destination survey specifically for the affected corridor, or

   b. Estimate a trip table from observed link volumes and (optionally) turning movements using LINKOD, or

   c. Perform a trip distribution analysis:

      (1) Using a network-based highway and transit planning model, or

      (2) Using quick-response estimation techniques.

- Total closure--the closure of all lanes in one or both directions of the highway being reconstructed

A corridor traffic management plan includes (1) a basic traffic-handling option for the highway being reconstructed, and (2) strategies to mitigate the travel impacts throughout the affected corridor. Impact mitigation strategies include (1) techniques to increase the capacity of the reconstruction zone, and (2) TSM-type improvements on alternative routes and modes.

Many factors influence the selection of the traffic-handling options that should be considered for a particular reconstruction project. Some of the major factors include the following:

- The space requirements to perform the reconstruction
- The time constraints for performing the work
- The volume of traffic that must be accommodated
- The availability of suitable alternative transportation facilities and services in the corridor
- The cost of the traffic management plan
- The goals and policies of the highway agency with respect to acceptable levels of travel impacts

In selecting a traffic-handling option, tradeoffs must be considered between savings in reconstruction costs and increases in traffic management and road user costs. Generally, as more roadway space is allocated to the reconstruction activity, reconstruction costs decrease, but traff ic management and road user costs increase. The travel impact evaluation process focuses on the traffic management and road user cost issues.

ESTIMATE THE CAPACITY OF THE RECONSTRUCTION ZONE

The first thing that must be done to evaluate a traffic-handling option is to determine the changes in traffic-handling capacity through the reconstruction zone. The capacity of the reconstruction zone is a major determinant of the magnitude of travel impacts that will result from the reconstruction project. It may be adequate to estimate the capacity for the most restrictive location, which would be the case if the highway being reconstructed served primarily through traffic. On the other hand, if the highway serves primarily short-trippers or if the project is conducted in phases, then it may be necessary to estimate the capacity of each segment.

Unfortunately, available data on the capacity of long-term reconstruction zones is limited. Chapter 6 of the 1985 Highway Capacity Manual (7) summarizes the available data. Another approach would be to use the standard capacity analysis procedures for the appropriate highway type to estimate the capacity through the reconstruction zone based upon the geometry of the reconstruction zone and the traffic composition data obtained during the inventory of the corridor. The review of highway capacity analysis procedures in Appendix B discusses some of the difficulties in estimating reconstruction zone capacity.

Capacity analysis procedures can be used to estimate the level of service and average speed through the work zone based upon existing traffic volumes. If the traffic-handling option provides an acceptable level of service, then the travel impacts may be restricted to the highway being reconstructed,and the evaluation may proceed directly to the estimation of operational and economic MOEs. If the level of service is unacceptable, then it is likely that traffic will divert from the highway being reconstructed and a corridor- wide evaluation should be conducted.

COMPARE CORRIDOR-WIDE VOLUME AND CAPACITY

If the capacity through the reconstruction zone is inadequate, then corridor-wide traffic volumes and capacities should be compared to determine whether the available capacity on alternative routes and modes in the corridor could compensate for the reductions in capacity on the highway being reconstructed. In this step, the corridor-wide traffic volumes and capacities determined in preceding steps are compared. The comparison of volumes and capacities should be made at critical screenlines. Since volumes and capacities may vary through the length of the corridor, it may be necessary to check several screenlines, including (1) the one running through the segment of the highway being reconstructed with the greatest reduction in capacity, and (2) the one with the highest total corridor volume.

If the total corridor-wide capacity appears to be adequate, then a good traffic control plan for the reconstruction zone and a good public information program may be sufficient to provide acceptable traffic flow throughout the corridor. In this case, the evaluation could proceed directly to the estimation of the changes in travel patterns in the corridor. If the total corridor-wide capacity appears to be inadequate, then it may be necessary to revise the traffic management plan.

REVISE TRAFFIC MANAGEMENT PLAN

If, in the previous step, it appears that the corridor-wide capacity would be inadequate to accommodate traffic flow at an acceptable level of service during reconstruction, then the traffic management plan should be revised to incorporate impact mitigation strategies. Impact mitigation strategies include:

- Traffic-control techniques to increase the capacity of the reconstruction zone
- TSM-type improvements to increase the capacity of alternative routes and modes

A number of traffic-control techniques might be employed to maximize the reconstruction zone capacity for a given traffic-handling option. Some of the capacity-enhancing techniques that were employed at the five reconstruction projects reviewed in this report (Pittsburgh, Boston, Philadelphia, Detroit, and Minneapolis) are as follows:

- Phasing reconstruction activities to minirnize the number of lanes closed and the length of section affected by lane closures at any point in time
- Using portable concrete median barriers and screens to separate the travel lanes from work areas or to separate opposing lanes of traffic
- Closing ramps or restricting ramps to HOVs only in the reconstruction zone
- Widening and upgrading shoulders for use as travel lanes
- Using exclusive, reversible lanes for peak-period, peak-direction through or HOV traffic
- Increasing the frequency of police and courtesy patrols through the reconstruction zone to reduce incident detection time
- Providing free tow truck service in the reconstruction zone to reduce incident response time

A variety of TSM-type improvements might be employed to increase the capacity of alternative routes and modes in order to mitigate the adverse travel impacts in the affected corridor. Tables 4 and 5 summarize the types of improvements in each category that have been incorporated into the traffic management plans for the five reconstruction projects reviewed in this report.

REVISE CORRIDOR-WIDE CAPACITY ESTIMATES

The traffic management plan being evaluated may include several of the impact mitigation strategies identified in Tables 4 and 5 in order to increase the capacity of the highway being reconstructed and/or the alternative routes and modes in the corridor. In this step the changes in the traffic-handling capacity of those routes and/or modes are estimated. Highway capacity analysis procedures could be used to estimate the changes in capacity associated with the impact mitigation strategies. It may be necessary to express capacities in terms of persons, instead of vehicles, if HOV services are available in the corridor.

ESTIMATE THE CHANGES IN TRAVEL PATTERNS IN THE CORRIDOR

A key step in a corridor-wide evaluation is to estimate how current users of the highway being reconstructed will respond to a particular traffic management plan and what the secondary impacts will be on current users of alternative routes and modes in the corridor. This is perhaps the most difficult step in the evaluation process because information on how motorists respond to reconstruction projects is extremely limited. The experience gained from the five reconstruction projects reviewed in this report provides valuable insight into the types of responses to expect. However, a much broader data base is required in order to assess the sensitivity of motorist responses to different levels of impact and to alternative traffic management strategies.

The experiences from the five projects reviewed in this report suggest that motorists respond to major reconstruction projects in one of five ways:

1. Cancellation of trips in the corridor, i.e., either cancel the trip altogether or change the trip destination to avoid the corridor
2. Spatial diversion, i.e., continue to travel in the corridor by automobile but on an alternative route
3. Temporal diversion, i.e., continue to travel in the corridor by automobile but at a different time of day
4. Modal diversion, i.e., continue to travel in the corridor but by a different mode
5. Continuation of normal travel patterns

TABLE 4. IMPROVEMENTS ON ALTERNATIVE HIGHWAY ROUTES IN THE CORRID

	Pittsburgh	Boston	Philadelphia	Detroit
Signal Operations Improvements e.g., Coordination Retiming New Signals Modernized Signals Temporary Signals	X	X	X	X
Other Operations Improvements e.g., Left-Turn Restrictions On-Street Parking Restrictions Reversible Lanes Signing/Lighting/Marking Improvements	X	X	X	X
Police Control at Key Locations	X	X	X	X
Coordinating Maintenance Schedules			X	X
Roadway Construction e.g., Minor Widening Addition of Turning Lanes Improved Connectors Repaving	X	X	X	X

TABLE 5. IMPROVEMENTS IN HIGH-OCCUPANCY VEHICLE AND PUBLIC TRANSPORTATION SERVICES

	Pittsburgh	Boston	Philadelphia	Detroit
New or Expanded Rail Service e.g., New Commuter Train Additional Cars on Existing Trains Extension of Rail Service Beyond Existing Terminus Additional Trains to Increase Service Frequency Additional Police for Security	X	X	X	
Expanded Bus Service e.g., New Express Buss Routes Additional Feeder Service to Commuter Train Additional Buses to Maintain/ Increase Pre-Reconstruction Headways Backup Buses On-Call in Case of Delays	X	X	X	X
Expanded Commuter Boat Service		X		
New or Expanded Park-and-Ride Lots	X	X	X	
New or Expanded Ridesharing Programs	X	X	X	X
Restricting Ramps to High-Occupancy Vehicles Only	X			
Reversible Lane through Reconstruction Zone for High-Occupancy Vehicles Only				

These motorist responses can be measured as changes in:

1. Trip generation rates
2. Trip distribution patterns, i.e., origin-destination trip tables
3. Mode split and/or auto occupancy rates
4. Traffic assignments among routes in the corridor, i.e., traffic volumes on all routes across a screenline through the corridor

The experiences from the five projects reviewed in this report suggest that the cancellation of trips in the corridor is an uncommon response and that changes in total corridor volumes are likely to be minor. The most common response of motorists in Pittsburgh, Boston, Philadelphia, and Detroit was spatial diversion, which was evidenced by changes in the allocation of total corridor volumes among alternative routes in the corridor. Temporal diversion, primarily earlier departure times, was also documented in Pittsburgh and Boston. Small amounts of modal diversion have also occurred. More detailed information on the observed motorist responses to the five projects is provided in Appendix C.

These experiences suggest that changes in trip generation rates and trip distribution patterns may be uncommon, and that traffic assignment procedures may be the most important tools in estimating changes in travel patterns. Changes in trip generation rates and in trip distribution patterns due to the cancellation of trips in the corridor are undesirable to business establishments in the corridor, because of the fear of losing customers. If such changes are predicted then it may be necessary to refine or eliminate the traffic management plan. Alternatively, the analyst may (1) assume that no changes in either trip generation rates or trip distribution patterns will occur, and (2) evaluate the changes in mode split and traffic assignments that would occur based upon that assumption.

Changes in travel patterns can be estimated using an analysis tool with traffic assignment capabilities (i.e., network-based highway and transit planning models, quick-response estimation techniques, and certain traffic simulation models). If an up-to-date network-based planning model for the affected corridor exists, then the required analyses could be performed with reasonable effort. However, considerable time and effort would be required if a new origin-destination trip table and a network representation of the corridor must be developed. A less time and labor-intensive approach would be to use non-network-based, quick-response estimation techniques. Another approach would be to use a traffic simulation model that has traffic assignment capabilities, but these, too, require considerable time and effort if a trip table and a network representation of the corridor must be developed.

ESTIMATE OPERATIONAL AND ECONOMIC MOEs

The objective of this step is to translate the changes in travel patterns into more meaningful measures of the travel impacts on motorists, such as travel time or average speed. Perhaps the most understandable measure is delay, i.e., the increase in travel times due to the reconstruction project. It may be desirable to provide delay estimates for the corridor as a whole as well as for individual routes in the corridor. Other useful corridor-wide MOEs include total vehicle-miles traveled and total vehicle-hours traveled. The corridor-wide MOEs can be estimated by network-based planning models, whereas route-specific MOEs, including travel times and speed, are better estimated using highway capacity analysis procedures or traffic simulation models.

It may also be desirable to translate the operational MOEs into road user costs in order to compare the costs and benefits (savings in road user costs) associated with the traffic management plan as a whole or with individual impact mitigation strategies. Most of the analysis tools do not estimate road user costs and, therefore, it may be necessary to compute costs manually. Generally, delay costs are the largest component of road user costs (in comparison with accident and vehicle operating costs). Delay costs can be estimated by multiplying the total vehicle hours of delay by an accepted dollar value of time.

If the MOEs are acceptable, then the traffic management plan may be finalized. If the MOEs are unacceptable, then it may be necessary to revise the traffic management plan and evaluate the revised plan.

FINALIZE TRAFFIC MANAGEMENT PLAN

The objective of the travel impact evaluation process is to provide highway agency officials the information needed to select among alternative traffic management plans. It should be re-emphasized that the process is an evaluation, not a decision-making, framework. The process is completed when decision makers have all the information they need to select a final traffic management plan for the reconstruction project.

3. GUIDELINES ON THE SELECTION OF APPROPRIATE ANALYSIS TOOLS

This section provides guidelines on the selection of appropriate analysis tools to evaluate the travel impacts of a given reconstruction project. First, the types of analysis tools that have potential application to the reconstruction project travel impact evaluation process are identified. Second, general considerations on the selection of appropriate analysis tools are discussed. Finally, more specific recommendations are made for selected types of projects.

AVAILABLE ANALYSIS TOOLS FOR RECONSTRUCTION PROJECT TRAVEL IMPACT EVALUATION

Available analysis tools with potential application to the travel impact evaluation process for highway reconstruction projects are grouped into five categories:

- Network-based highway and transit planning models
- Quick-response estimation techniques
- Highway capacity analysis procedures
- Traffic simulation models
- Traffic optimization models

Table 6 summarizes the steps of the travel impact evaluation process in which each tool could be used.

Network-based highway and transit planning models are particularly useful if a corridor-wide evaluation is required. Network-based planning models could be used in several steps of the evaluation process. The primary role of the planning models would be in the traffic assignment and mode split analyses required to estimate changes in corridor travel patterns. In the inventory of the affected corridor, they could be used to identify the origins and destinations of the current users of the highway being reconstructed. These models might also be used to estimate corridor-wide operational MOEs, such as total vehicle-miles traveled and vehicle-hours traveled.

TABLE 6. APPLICATIONS OF AVAILABLE ANALYSIS TOOLS

STEPS IN TRAVEL IMPACT EVALUATION PROCESS	TOOLS				
	Network-Based Planning	Quick-Response Estimation	Highway Capacity Analysis	Traffic Simulation	Traffic Optimization
Inventory the Affected Corridor	X	X	X	X	
Identify Traffic-Handling Options					
Estimate the Capacity of the Reconstruction Zone			X		
Compare Corridor-Wide Volume and Capacity					
Revise Traffic Management Plan			X	X	X
Revise Corridor-Wide Capacity Estimates			X		
Estimate the Change in Travel Patterns in the Corridor	X	X		X	
Estimate Operational and Economic MOES	X	X	X	X	X

Quick-response estimation techniques could be used as an alternative to network-based planning models. They are simplified, non-network-based techniques for performing the same travel demand forecasting functions as network-based planning models. Key issues in selecting between network-based planning models and quick-response estimation techniques are identified in the discussion that follows on general considerations in selecting appropriate analysis tools.

Highway capacity analysis procedures play a vital role throughout the travel impact estimation process. The magnitude of the impact is directly related to the magnitude of the reduction in capacity on the highway being reconstructed. Capacity analysis procedures are used to estimate the capacity of the reconstruction zone as well as alternative routes and modes. Capacity analysis procedures may be useful in the design of impact mitigation strategies that need to be incorporated into the traffic management plan. Capacity analysis procedures may also be used to estimate operational MOEs, including level of service and average speed, on both the highway being reconstructed and alternative routes. It is essential that capacities be accurately estimated in order to produce realistic projections of travel impacts and to develop a cost-effective traffic management plan.

Traffic simulation models may be used to simulate existing traffic conditions in the corridor and to estimate operational MOEs for alternative traffic management plans. Those traffic simulation models with traffic assignment capabilities may also be useful in evaluating the changes in travel patterns resulting from a reconstruction project. Traffic simulation models would be a primary tool for computing operational and economic MOEs, particularly when the time-varying nature of traffic flows is important or when geometries are complex.

The principal role of traffic optimization models in the travel impact evaluation process would be in the refinement of the improvements on alternative routes that are included as a component of a candidate traffic management plan. Traffic optimization models also provide estimates of operational and economic MOEs.

Table 2 listed the analysis tools in each category that are reviewed for this report. In many cases several tools could be used to perform a particular analysis, but with a different level of effort and different level of accuracy and detail in the output. The actual level of effort required to use the various tools depends on several factors including:

- The user’s familiarity with the tool

- The availability of previous applications of the tool in the same corridor
- The availability of data
- The scope of the analysis

It is difficult to define the level of effort needed to use each tool in absolute terms. However in relative terms, network-based tools (highway and transit planning models and certain traffic simulation models) require greater effort than tools that are not network-based.

The level of accuracy and detail of the output from the tools depends on several factors including:

- The level of accuracy and detail of the input data
- The number of simplifying assumptions made in the analysis
- The effort taken to calibrate the tool to known base conditions
- The validity of the analytical approach for the particular application

Analysts should clearly understand the reliability of the tools used before interpreting results obtained. There have been few reconstruction related applications of most of the analysis tools reviewed. Therefore, it is difficult to judge the accuracy of the procedures. However, a general indication of the appropriateness of the tools for use in the reconstruction project travel impact evaluation process is provided in the detailed reviews in Appendix B.

It must be emphasized that given the limited information currently available on motorist responses to major highway reconstruction projects and the lack of real-world applications of most of the analysis tools in a reconstruction context, the use of all of the analysis tools must be tempered with a thorough knowledge of local conditions and with sound judgment.

GENERAL CONSIDERATIONS IN SELECTING APPROPRIATE ANALYSIS TOOLS

The travel impact evaluation process could be performed using several different combinations of analysis tools. Analysis tools vary in terms of their capabilities, accuracy, and detail as well as their data, time, computer, and manpower requirements.

The analysis tools that are most appropriate for a particular project depend on a number of factors, including the following:

- The nature, magnitude, and complexity of the project
- The type of highway being reconstructed
- The amount of time needed to complete the reconstruction project
- The length of the highway segment being reconstructed
- The volume of traffic that will be impacted
- The size and complexity of the affected corridor
- The availability of unused capacity on alternative routes
- The potential for shifting trips to transit or other HOV modes
- The potential for TSM improvements on alternative routes and modes
- The experience of the planning or highway agency staff
- The time and personnel available for planning activities
- Computer and data resources available

Primarily the magnitude and duration of the capacity reductions on the highway being reconstructed determine the appropriate scope and level of effort for the travel impact evaluation. Three categories of capacity reductions were defined earlier: (1) minor capacity reductions, (2) partial closures, and (3) total closures. In general, the greater the reduction in capacity on the highway being reconstructed and the longer the duration of the reductions, the more serious the potential travel impacts, the greater the investment in traffic management, and the greater the scope and level of effort justified in the travel impact evaluation.

Figure 2 illustrates the major decisions that must be made in selecting the appropriate analysis tools. The most critical decision involves the scope of the evaluation; i.e., whether a corridor-wide evaluation is required or whether the evaluation may be restricted to the highway being reconstructed. The level of effort for a corridor-wide evaluation is greater than for an evaluation restricted to the highway being reconstructed; therefore, a corridor-wide evaluation should be performed only when justified. In general,

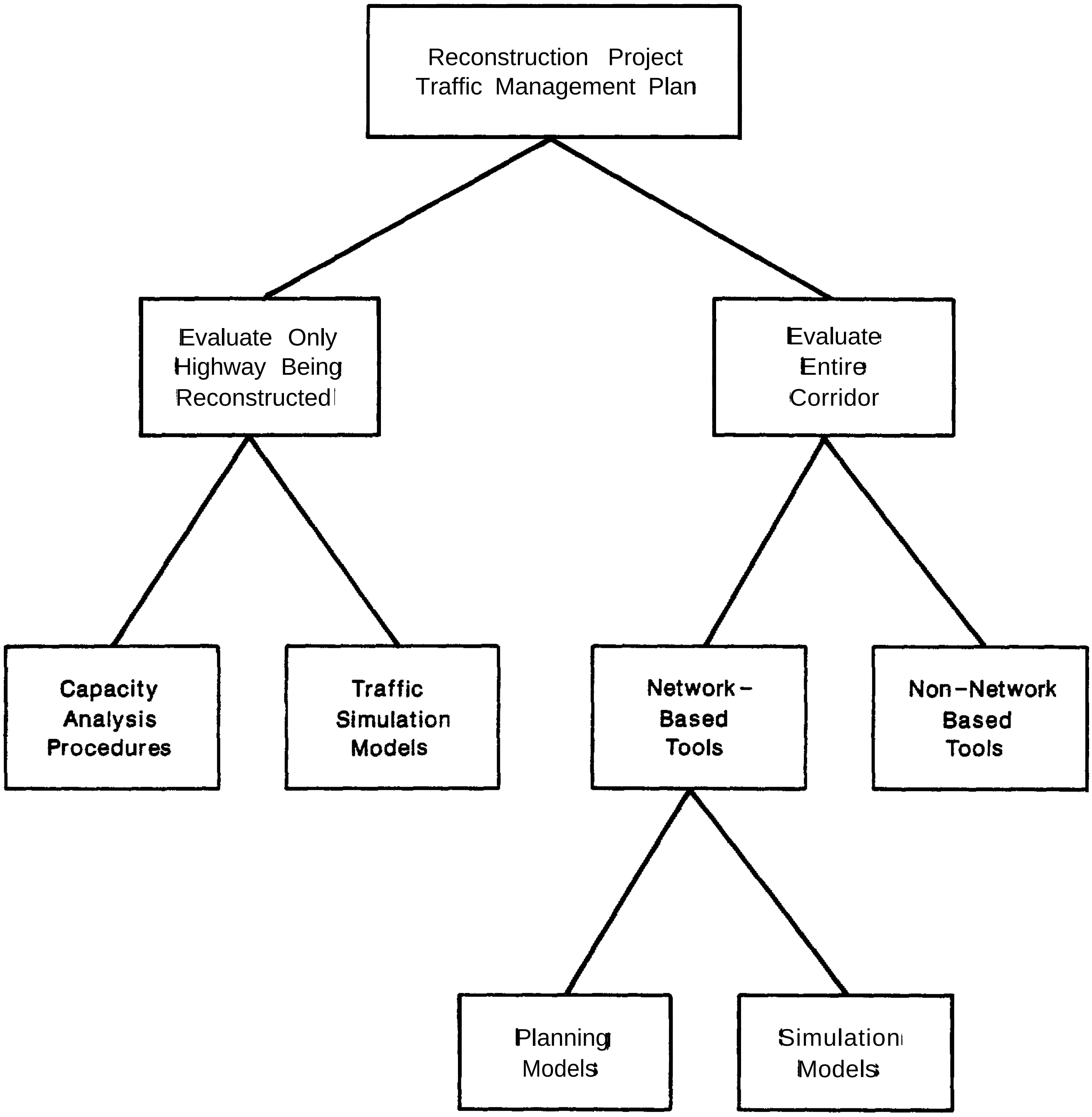

Figure 2. Decision Tree for Selecting Analysis Tools for the Travel Impact Evaluation Process

if a partial or total closure is being considered, then a corridor-wide evaluation would be justified; whereas, if only minor capacity reductions are being considered, then the evaluation could be restricted to the highway being reconstructed. A corridor-wide evaluation would consider the highway being reconstructed as well as alternative routes and modes in order to estimate the nature and magnitude of the changes in travel patterns that are likely to occur throughout the affected corridor.

After the scope of the evaluation has been determined, the appropriate analysis tools must be selected. If the scope of the evaluation is restricted to the highway being reconstructed, then two types of analysis tools that might be used are highway capacity analysis procedures or traffic simulation models. If a corridor-wide evaluation is appropriate, then an analysis tool with traffic assignment capabilities may be necessary. The following paragraphs discuss the key considerations in determining the appropriate scope and level of effort for the travel impact evaluation.

Evaluate Only Highway Being Reconstructed

Generally, if only minor capacity reductions are planned through the reconstruction zone, then the travel impact evaluation may be restricted to the highway being reconstructed. In most cases, if the same number of lanes are maintained through the reconstruction zone or if lanes are closed only during off-peak periods, then it is unlikely that significant travel impacts would extend beyond the highway being reconstructed, and it may be appropriate to restrict the travel impact evaluation to the highway being reconstructed.

If the scope of the evaluation is restricted to the highway being reconstructed, then two types of analysis tools should be considered: highway capacity analysis procedures and traffic simulation models. Highway capacity analysis is essential for any travel impact evaluation. Therefore, the key decision is whether or not the additional effort to use a traffic simulation model is justified. Simulation models may be required in order to estimate operational MOEs for alternative geometric configurations or control strategies that cannot be evaluated adequately using highway capacity analysis procedures. Simulation models are particularly useful in evaluating (1) the variations in operating conditions over time, and (2) the interrelated effects on operating conditions of several roadway features. Simulation models are available for both freeway facilities and arterial streets. In Appendix B. freeway simulation models are further subdivided into freeway lane closure models, which are designed specifically to evaluate traffic flow through lane closure bottlenecks, and freeway corridor simulation models, which can evaluate the impacts of a broad range of geometric and traffic control conditions.

Evaluate Entire Corridor

For major highway reconstruction projects in which significant reductions in capacity (i.e., partial or total closures) are being considered, travel impacts are likely to extend beyond the highway being reconstructed. Therefore, the impact evaluation should be corridor-wide. A major issue in a corridor-wide evaluation is how traffic will be reallocated among routes in the corridor. Therefore, a corridor-wide evaluation requires an analysis tool with traffic assignment capabilities.

Three types of analysis tools have traffic assignment capabilities:

- Network-based highway and transit planning models
- Network-based freeway corridor simulation models
- Non-network-based quick-response estimation techniques

All three types of analysis tools require an origin-destination trip table. Table 3 identified the alternative ways to obtain an origin- destination trip table. If an existing trip table is not available from a regional transportation model or a previous study, considerable effort would be required to develop one. Network-based planning models and freeway corridor simulation models use a link-node representation of the transportation network, which also requires considerable effort to create. Quick-response estimation techniques use a more simplified, non-network-based, representation of the transportation system and, as a result, require less effort to use. The key considerations in selecting among the three types of analysis tools are:

- The complexity of the traffic management plan for the reconstruction project
- The size of the corridor (number of alternative routes) that is likely to be affected
- The time, data, and labor resources that are available

Network-based models have important analytical capabilities but are time- data-, and labor-intensive and, therefore, may be appropriate only for large and complex projects with potentially severe travel impacts. Quick-response estimation techniques are quicker and easier to use. However, they were not designed to analyze large or complicated corridors, and they may not provide the same level of detail or sensitivity to key variables as a network-based model. The additional effort required to use a network-based model may be justified only for projects in which significant capacity reductions (at least one lane closed) are anticipated over an extended length of roadway (at least several miles) for an extended period of time (at least several months).

Much of the effort required to use network-based planning or simulation models, is related to developing an origin-destination trip table and creating a link-node representation of the transportation network. Therefore, the availability of a validated, network-based, regional transportation model that has an up-to-date trip table and transportation network would broaden the range of projects for which the analysis capabilities of a network-based analysis tool could be used with a reasonable level of effort. If a validated regional model is not available, but a trip table and network is available from a previous regional study; then the use of network-based analysis tools may still be appropriate even though it may be necessary to update the trip table. In the absence of either a validated regional model or a trip table and network from a previous study, the level of effort required to develop both a new trip table and network representation is considerable and, therefore, may be justified only for particularly large, lengthy, complex and/or controversial projects.

In selecting between a network-based planning model and a freeway corridor simulation model, the relative strengths of the two types of models must be considered. The principal application of a planning model is in estimating the magnitude of changes in corridor-wide traffic patterns. The principal application of traffic simulation is to evaluate the time-varying nature of traffic flows and the effect of alternative geometric and traffic control conditions on traffic operations. Therefore, if alternative geometric and traffic control conditions must be evaluated with considerable accuracy, then a simulation model should be used.

The principal alternative to network-based models is non-network-based, quick-response estimation techniques. Quick-response estimation techniques are simplified procedures for travel demand forecasting that make maximum use of transferable parameters in order to minimize their time and data requirements. They can provide acceptable levels of accuracy for many applications. However, even with the quick-response estimation techniques, a considerable effort would be required if the affected corridor is large.

SPECIFIC RECOMMENDATIONS FOR SELECTED TYPES OF RECONSTRUCTION PROJECTS

Specific recommendations are outlined in the following paragraphs on (1) the steps in the evaluation process, and (2) the types of analysis tools that may be appropriate for the three general categories of capacity reductions (i.e., minor capacity reduction, partial closure, and total closure). There are numerous ways to perform a travel impact evaluation and numerous combinations of analysis tools that could be used effectively.

The basic principle is that the level of effort should correspond to the level of capacity reductions and the severity of the potential travel impacts. The procedures that follow represent three of the numerous approaches that could produce useful results.

Minor Capacity Reductions

When the reconstruction activity can be performed with only minor capacity reductions through the reconstruction zone, the travel impacts are generally confined to the highway being reconstructed. Traffic management plans which involve only minor capacity reductions typically have the following characteristics:

- The same number of lanes are maintained through the reconstruction zone, at least during peak periods, by using shoulders as temporary lanes or by narrowing lane and shoulder widths
- Short-term, partial lane closures are permitted only during off-peak periods
- Ramps are closed temporarily, as necessary

Generally, when only minor capacity reductions are being considered, it would be appropriate to restrict the travel impact evaluation to the highway being reconstructed. A recommended procedure for evaluating the travel impacts of a reconstruction project that involves only minor capacity reductions is outlined below:

I. Inventory the affected corridor.

A. Inventory the highway being reconstructed.

1. Inventory the geometry and traffic control characteristics of the highway being reconstructed.
2. Estimate the existing capacity of the highway being reconstructed using highway capacity analysis procedures.

B. Inventory the current usage of the highway being reconstructed.

1. Collect traffic volume and vehicle occupancy data.
2. Collect transit ridership data.

C. Estimate operational MOEs for existing conditions.

1. Perform travel time studies.
2. Alternatively, use highway capacity analysis procedures to estimate level of service, average speeds, and travel times.
3. Alternatively, if the time-varying nature of traffic flow is important or if several geometric features have an interrelated effect on traffic flow, use a traffic simulation model to estimate travel times and average speeds.

II. Estimate the traffic-handling capacity of the reconstruction zone using highway capacity analysis procedures.

III. Estimate operational and economic MOEs during reconstruction.

A. Estimate changes in level of service, average speed, and travel time during reconstruction using highway capacity analysis procedures.

B. Alternatively, use traffic simulation models if any of the following cases apply:

1. If lane closures are being considered, use freeway lane closure models to estimate the delays and additional road user costs that may result.

2. If the time-varying nature of traffic flow is important or if several geometric features have an interrelated effect on traffic flow, then use freeway corridor simulation models to estimate operational MOEs.
3. If an urban arterial is being reconstructed, use urban arterial simulation models to estimate operational MOEs.

C. If the MOEs are unacceptable, revise the traffic management plan.

Partial Closures

In many cases, it may be impossible, impractical, or undesirable to maintain the same number of lanes through the reconstruction zone. Instead, it may be necessary to close some, but not all, lanes in one or both directions of the highway being reconstructed throughout the duration of the project. If the lane closures would reduce the capacity of the reconstruction zone below demand volumes for significant parts of the day, then significant changes in traffic volumes are likely to occur and the travel impact evaluation should be corridor-wide in scope. In some cases, strategies should be considered to mitigate the adverse impacts of the partial closure of the highway being reconstructed. Strategies may include traffic-control techniques to increase the capacity of the reconstruction zone or TSM-type improvements on alternative routes and modes.

Any of the three types of analysis tools with traffic assignment capabilities (i.e., network-based planning models, freeway corridor simulation models, or quick-response estimation techniques) could serve as the backbone of the evaluation. The key considerations in determining which type of tool to use have already been discussed. In general, network-based tools offer the potential for more detailed and accurate analyses but require more effort to use than non-network-based tools. Therefore, network-based tools should be used only if the complexity of the traffic management plan and the size of the corridor justify the additional effort. If the geometry of the reconstruction zone is relatively uncomplicated and the number of alternative routes that are likely to be affected is small, then non-network-based, quick-response estimation techniques may be adequate to perform the corridor-wide evaluation.

The procedure that follows is based upon the use of quick-response estimation techniques:

I. Inventory the affected corridor.

A. Define the boundaries of the affected corridor to include all routes likely to be affected by the reconstruction project.

B. Inventory the highway being reconstructed and all important alternative highway and transit routes.

1. Inventory the geometry and traffic control characteristics of affected highway routes and the service characteristics of affected transit routes.
2. Estimate the current capacity of all highway links and transit routes using highway capacity analysis procedures.

C. Inventory the current usage in the corridor.

1. Collect traffic volume and vehicle occupancy data on all affected highway links.
2. Collect transit ridership data on all transit routes.

D. Estimate operational MOEs for existing conditions.

1. Perform travel time studies on the highway being reconstructed and on important alternative routes.
2. Alternatively, use highway capacity analysis procedures to estimate levels of service, average speeds, and travel times.

II. Estimate the traffic-handling capacity of the reconstruction zone using highway capacity analysis procedures.

III. Compare corridor-wide volumes and capacity.

A. Identify critical screenlines.

B. Sum the capacities of alternative routes and the capacity of the reconstruction zone across the screenline.

C. Sum the traffic volumes across the screenline.

D. If total corridor volumes exceed total corridor capacity, then revise the traffic management plan to increase the capacity of either the reconstruction zone or alternative routes and modes.

IV. Estimate the capacity in the corridor with the revised traffic control plan using highway capacity analysis procedures.

V Estimate the changes in corridor travel patterns using quick-response estimation procedures.

A. Obtain origin-destination trip table using one of the approaches identified in Table 3.

B. Use a quick-response traffic assignment procedure to estimate changes in assigned link volumes across critical screenlines.

C. If assigned volumes are excessive for certain links, then revise the traffic management plan.

VI. Estimate operational and economic MOEs during reconstruction.

A. Estimate the changes in level of service, average speeds, and travel times using highway capacity analysis procedures.

B. If desired, multiply changes in travel time by an appropriate value of time to estimate the additional road user costs associated with the delays caused by the reconstruction project.

C. If the MOEs are unacceptable, revise the traffic management plan.

Total Closure

The total closure of one or both directions of the highway being reconstructed would cause the most severe travel impacts of any traffic-handling option, but would be a viable option if resulting savings in reconstruction costs outweighed the increases in road user costs. Unless considerable unused capacity existed on alternative routes in the corridor, extensive improvements would probably be needed on alternative routes and modes in order to mitigate the adverse impacts. A major planning effort would be required to develop an adequate corridor traffic management plan. The magnitude of the potential investment in the traffic management plan would justify the use of a network-based analysis tool.

The following procedure, based upon the use of a network-based analysis tool (a planning model and/or a traffic simulation model), could be used for such a planning effort:

I. Inventory the affected corridor.

A. Define the boundaries of the affected corridor to include all routes on which traffic patterns are likely to be affected by the reconstruction project.

B. Inventory the highway being reconstructed and all important alternative highway and transit routes.

1. Inventory highway network link geometry and traffic control characteristics. (Collect all link data required by the network-based analysis tool selected for use.)
2. Estimate the current capacity of all highway links and transit routes using highway capacity analysis procedures.

C. Inventory the current usage in the corridor.

1. Collect traffic volume and vehicle occupancy data.
2. Collect transit ridership data on all transit routes.

D. Estimate operational MOEs for existing conditions.

1. Perform travel time studies on the highway being reconstructed and on all important alternative routes.
2. Alternatively, use highway capacity analysis procedures to estimate levels of service, average speeds, and travel times.
3. Alternatively, use a validated network-based traffic assignment procedure to estimate total corridor vehicle-miles and vehicle-hours traveled as well as average speeds and travel times on selected routes.
4. Alternatively, use a validated freeway corridor simulation model with traffic assignment capabilities to estimate average speeds and travel times on selected routes.

II. Estimate the traffic-handling capacity of the reconstruction zone using highway capacity analysis procedures.

III. Compare corridor-wide volumes and capacity.

A. Identify critical screenlines.

B. Sum the capacities of alternative routes and the capacity of the reconstruction zone across the screenline.

C. Sum the traffic volumes for the same routes across the screenline.

D. If total corridor volumes exceed total corridor capacity, then refine the traffic management plan to increase the capacity of either the reconstruction zone or alternative routes and/or modes.

IV. Estimate the traffic-handling capacity of alternative routes and modes with the proposed improvements using highway capacity analysis procedures.

V. Estimate the changes in corridor travel patterns using a network-based analysis tool.

A. Obtain origin-destination trip table using one of the approaches identified in Table 3.

B. Use a network-based traffic assignment procedure to estimate changes in assigned link volumes across critical screenlines.

C. If assigned volumes are excessive for certain links, then refine the traffic management plan.

VI. Estimate operational and economic MOEs during reconstruction.

A. Estimate the changes in level of service, average speeds, and travel times using highway capacity analysis procedures.

B. Alternatively, use a network-based analysis tool to estimate changes in total corridor vehicle-miles and vehicle-hours traveled as well as changes in average speeds and travel times on selected routes.

C. If desired, multiply changes in travel time by an appropriate value of time to estimate the additional road user costs associated with the delays caused by the reconstruction project.

D. If the MOEs are unacceptable, refine the traffic management plan.

4. SUMMARY

This report has presented (1) a process for evaluating the travel impacts of major highway reconstruction projects, and (2) guidelines for selecting appropriate analysis tools. The objective of the evaluation process is to estimate the operational and economic MOEs that decision makers need to select among alternative traffic-handling options.

The major determinants of the types of analyses that must be performed are the magnitude of capacity reductions on the highway being reconstructed and the severity of the potential travel impacts throughout the corridor. The scope of the evaluation may be restricted to the highway being reconstructed if the capacity reductions are minor and traffic is unlikely to divert away from the reconstruction zone. The scope of the evaluation should be corridor-wide if capacity reductions are expected to be significant enough to prompt motorists throughout the corridor to change their travel patterns.

If the scope of the evaluation is restricted to the highway being reconstructed, then the analyses can be performed using highway capacity analysis procedures or traffic simulation models. Simulation models are particularly useful when the time-varying nature of traffic flows should be considered, or when a series of geometric features have an interrelated effect on traffic flow.

If the scope of the evaluation is corridor-wide, then an analysis tool with traffic assignment capabilities (network-based highway and transit planning models, quick-response estimation techniques, or freeway corridor simulation models) is required. In a corridor-wide evaluation, the major issues are how traffic will reallocate itself among alternative routes and modes in the corridor, and what the resulting operational and economic impacts will be.

This report provides reviews of a representative sample of the available analysis tools with potential application to the travel impact evaluation process for reconstruction projects as well as summaries of the planning efforts and experiences of five major reconstruction projects. Appendix A summarizes the analysis capabilities, data requirements, output, computer needs, and availability of the analysis tools reviewed. Appendix B provides more detailed reviews of the analysis tools, including discussions of each tool's application and purpose, use, limitations, data requirements, advantages and disadvantages, success at forecasting travel during actual reconstruction, and appropriateness for reconstruction project travel impact evaluation. Appendix C reviews the planning efforts undertaken, traffic management strategies employed, and actual travel impacts observed during major highway reconstruction projects in Pittsburgh, Boston, Philadelphia, Detroit, and Minneapolis.

Experiences with many of the tools in a reconstruction context have been limited. Furthermore, only limited amounts of data are available on key issues including (1) the capacity of a long-term reconstruction zone (and the factors that influence capacity), and (2) the response of motorists to major highway reconstruction projects. It is important to continue to collect additional data and to document all available experiences with highway reconstruction traffic impact evaluation so that analysis tools and planning procedures for major highway reconstruction projects may be improved. Such improvements should lead to more cost-effective traffic management plans and more acceptable levels of travel impacts.

APPENDIX A

SUMMARIES OF AVAILABLE ANALYSIS TOOLS WITH POTENTIAL APPLICATION TO THE RECONSTRUCTION PROJECT TRAVEL IMPACT EVALUATION PROCESS

This appendix provides one page summaries of available analysis tools with potential application to the reconstruction project travel impact evaluation process. Analysis tools are grouped into five categories:

- o Network-based highway and transit planning models
- o Quick-response estimation techniques
- o Highway capacity analysis procedures
- o Traffic simulation models
- o Traffic optimization models

The summaries discuss the following features of the analysis tools:

- o Analysis capabilities
- o Data requirements
- 0 output
- o Computer needs
- o Availability

The objective of this appendix is to summarize the key features of the analysis tools reviewed so that readers may quickly evaluate their potential use for a particular application. The reader is referred to the more detailed reviews in Appendix B for additional insights into how the various tools might be used in the reconstruction project travel impact evaluation process.

NETWORK-BASED HIGHWAY AND TRANSIT PLANNING MODELS

Analysis Capabilities

- o Perform traffic assignment analyses to evaluate changes in the allocation of trips among routes in the corridor resulting from a reconstruction project using various traffic assignment techniques (i.e., iterative or incremental capacity restraint assignment or equilibrium assignment)
- o Perform the select link analyses such as subarea analysis, ramp analysis, and freeway weaving analysis
- o Perform trip distribution (Gravity Model) analyses to obtain trip tables
- o Display and plot network attributes and assignment results

Data Requirements

- o Network link data: link length, connections, speed, and capacity; and optionally, observed ground count volumes or peak-hour capacities
- o Zonal productions and attractions and trip length frequency
- o Prohibited turn data and node coordinate data (optional)
- o Description of reconstruction area in terms of the characteristics of the affected links (i.e., link location and capacity)

Output

- o Report of the travel patterns in terms of updated-assigned volumes, travel impedances, and link speeds
- o Plot of network attributes and assignment results
- o Vehicle-Miles Traveled/Vehicle-Hours Traveled

Computer Needs

- o Computer needs vary depending upon the individual package used

Availability

- o Available from various vendors depending upon zone requirements and desired level of detail. For specifics of individual packages please see the Microcomputers in Transportation Software and Source Book (2).

See page B-2 in Appendix B for more detailed information.

QUICK-RESPONSE ESTIMATION TECHNIQUES: NCHRP 187 Manual Methods

Analysis Capabilities

- Perform simplified travel demand forecasting analyses to obtain trip tables; identify users of reconstruction segment; compare corridor-wide and individual link volumes for the different traffic-handling options
- Estimates changes in mode split and vehicle trips resulting from improvements in HOV services

Data Requirements

- Land use and socioeconomic characteristics; zonal network with centroids; zonal productions and attractions
- Transit fares, auto operating costs, attraction-end parking costs
- Urban area population
- Knowledge of the highway network

Output

- Number of trips for a given land use (Trip Generation); origin-destination trip table (Trip Distribution); corridor-wide and individual-link volumes (Traffic Assignment Procedures)
- Revised mode shares (Mode-Choice Analysis); number of vehicle trips on a given facility (Automobile-Occupancy Characteristics)

Computer Needs

- Procedures are performed manually

Availability

- Available from: Transportation Research Board
  National Academy of Sciences
  2101 Constitution Avenue, N.W.
  Washington, D.C. 20418
  202-334-3218

See page B-8 in Appendix B for more detailed information.

QUICK-RESPONSE ESTIMATION TECHNIQUES:
NCHRP 255 Traffic Assignment Refinement Techniques

Analysis Capabilities

- o Refinement of system-level or subarea-level assignments produced by the four-step travel demand modeling process
- o Screenline refinement for analyzing changes in corridor capacity
- o Select link analysis to estimate origin-destination travel patterns for trips traversing a specified link or group of links
- o Detailed network analysis for estimating trip volumes for networks more detailed than those typically included in a regional study

Data Requirements

- o Zonal data (productions and attractions) for base and forecast year
- o Highway network for base and forecast year. The forecast year needs to be close to the year that reconstruction will take place
- o Highway assignments for base and forecast year
- o Base-year traffic counts

Output

- o Refined traffic volume estimates for links included in the original network or links added to the network during the analysis
- o Origin-destination data for trips traversing the link(s) of interest

Computer Needs

- o A network-based travel demand modeling package such as UTPS or one of the microcomputer packages. The package needs to have a select link analysis procedure and a subarea window or subarea focusing procedure
- o The NCHRP 255 procedures can be applied manually or using a LOTUS i-2-3 spreadsheet template

Availability

- o NCHRP 255 Templates: Project Support Branch (HPN-22)
  Office of Planning
  Federal Highway Administration
  Washington, DC 20590
  202-366-2186

See page B-13 in Appendix B for more detailed information.

QUICK-RESPONSE ESTIMATION TECHNIQUES:
LI NKOD

Analysis Capabilities

- o Estimate origin-destination trip tables for highway traffic in small areas based on observed link volumes and (optionally) turning movement counts

Data Requirements

- o Observed volumes on links and (optionally) turning movements at intersections
- o Functional classification of the facility, length of link, number of moving lanes, speed of facility at low traffic volumes, travel time at zero volume and at capacity, capacity in vehicles per hour
- o Zonal productions and attractions
- 0 Intersection cycle time
- o Initial trip table (optional)

Output

- o Refined origin-destination trip table
- o Link files (assigned link volumes, increases in travel time when highway is at capacity, turn movements with and without assigned volumes)

Computer Needs

- o LINKOD requires an IBM 370/165 (mainframe) compatible computer with at least 256 K memory

Availability

- o Documentation: National Technical Information Service U.S. Department of Commerce
  5285 Port Royal Road
  Springfield, Virginia 22161

- o Software: Systems and Software Support Branch (HTO-23)
  Office of Traffic Operations
  Federal Highway Administration
  Washington, DC 20590
  202-366-2 186

See page B-19 in Appendix B for more detailed information.

QUICK-RESPONSE ESTIMATION TECHNIQUES: TRIPS

Analysis Capabilities

- Updates an existing origin-destination trip table
- Identifies current user's of the reconstruction segment by origin and destination, and could estimate changes in origin-destination patterns for each reconstruction option

Data Requirements

- Number of zones in network
- Number of paths, number of links (links compose paths), links used on a given path, traffic counts for each link
- Origins and destinations
- An initial trip table

Output

- Refined trip table

Computer Needs

- TRIPS can be run on an IBM PC/MS DOS compatible computer with a 512 K RAM

Availability

- Test Copies: McTRANS
  University of Florida
  512 Weil Hall
  Gainesville, FL 32611
  904-392-0378

See page B-19 in Appendix B for more detailed information.

QUICK-RESPONSE ESTIMATION TECHNIQUES: MODE CHOICE

Analvsis Capabilities

- o Estimates changes in mode split and auto occupancy resulting from changes in transit operations and/or policy

Data Requirements

- o Zonal data: subgroup population, average number of persons per household, income, cars per household, drivers per household, proportion of subgroup population which are principal wage earners in household
- o Level-of-service attributes for each mode: one-way distance, parking cost, auto cost per mile, one-way fare for transit, one-way out-of-vehicle travel time and in-vehicle travel time

Output

- o Estimates of the number of commuters between zones taking transit, sharing a ride, or driving alone

Computer Needs

- o MODE CHOICE requires an IBM PC/MS DOS compatible computer with DOS version 2.0 or later
- o Supporting software (necessary for operation): LOTUS l-2-3

Availability

- o Available from: McTRANS
University of Florida
512 Weil Hall
Gainesville, FL 32611
904-392-0378

See page B-23 in Appendix B for more detailed information.

QUICK-RESPONSE ESTIMATION TECHNIQUES:
RTD Pivot PoInt LogIt Model

Analysis Capabilities

- o Estimates changes in mode split resulting from changes in transit operations and/or policy

Data Requirements

- o Base mode shares (for drive alone, shared ride, and transit for each trip purpose)
- o Changes in in-vehicle travel time and out-of-vehicle travel time
- o Average Carpool size
- o One-way travel distance
- o Annual income
- o Presence or absence of shared-ride incentive
- o Level-of-service changes (includes the operations or policy changes to be analyzed--transit fares, headways, access/egress times, parking costs, accessibility to zone by drive alone or shared ride).

Output

- o Revised mode shares for drive alone, shared ride, and transit

Computer Needs

- o RTD Pivot Point Logit Model requires an IBM PC/MS DOS compatible computer with DOS version 2.0 or later
- 0 Supporting software (necessary for operation): SuperCalc 3

Availability

o Available from: McTRANS
University of Florida
512 Weil Hall
Gainesville, FL 32611
904-392-0378

See page B-23 in Appendix B for more detailed information.

HIGHWAY CAPACITY ANALYSIS PROCEDURES: Highway Capacity Software

Analysis Capabilities

- o Freeways: (1) Operational Analysis to estimate operational MOEs for basic, ramp, and weaving segments, or (2) Design Analysis to determine the number of lanes required to accommodate a specified flow rate at a desired level of service
- o Signalized Intersections: (1) Operational Analysis to estimate operational MOEs, or (2) Planning Analysis to determine whether existing geometries have adequate capacity to accommodate projected demand volumes
- o Arterials: Operational Analysis to estimate operational MOEs

Data Requirements

- o Roadway conditions: type of facility and its development environment, number of lanes, lane and shoulder widths, design speeds, alignments
- o Traffic conditions: volumes and peaking characteristics; distribution of vehicles by type, direction, movement, and lane
- 0 Control conditions: type of control (STOP, YIELD, and signal); signal phasing, timing, and progression

Output

- o Freeways: operational MOEs including capacity, level of service, speed, and density
- o Signalized Intersections: operational MOEs including capacity, level of service, and average stopped delay
- o Atterials: operational MOEs including level of service, total travel time, average delay per vehicle, average speed

Computer Needs

- o FHWAs Highway Capacity Software runs on IBM-PC/MS-DOS vcompatible computers with DOS version 2.0 or later and at least 384 K of memory

Availability

o Available from: McTRANS
University of Florida
512 Weil Hall
Gainesville, FL 32611
904-392-0378

See page B-26 in Appendix B for more detailed information.

TRAFFIC SIMULATION MODELS:
QUEWZ

Analysis Capabilities

- Estimate queue lengths and additional road user costs resulting from freeway work zone lane closures
- Identify schedules for lane closures such that queuing will not exceed a user-specified queue length in miles or delay in minutes

Data Requirements

- Configuration of the Work Zone: lane closure strategy (single direction or crossover), length of restricted capacity, total number of lanes and number of open lanes through the work zone in each direction
- Schedule of Work Activity: beginning and ending hours of restricted capacity, beginning and ending hours of work activity
- Traffic Volumes: directional hourly traffic volumes
- Alternative Values for Model Defaults: cost update factor, percentage of trucks, parameters for a speed-volume curve, work zone capacity, maximum acceptable delay to motorists, critical length of queue

Output

- Summary of Travel Impacts: hourly estimates of diverted traffic, volume through the work zone, section capacity, approach speed, work zone speed, average queue length, additional road user costs
- Acceptable Lane Closure Schedule

Computer Needs

- Microcomputer version runs on IBM PC or compatible machines
- Mainframe version requires an ANSI 77 FORTRAN or WATFIV compiler

Availability

- Available from: Texas Transportation Technology Transfer
  Technology Resource Center
  Texas Engineering Extension Service
  The Texas A&M University System
  College Station, TX 77843-8000
  409-845-4369

See page B-33 in Appendix B for more detailed information.

TRAFFIC SIMULATION MODELS:
FREWAY

Analysis Capabilities

- o Estimate the capacity of basic freeway segments under normal operating conditions and during work zone lane closures
- o Estimate queuing characteristics resulting from freeway work zone lane closures

Data Requirements

- o To estimate capacity under normal operating conditions: number of lanes, lane widths, lateral clearances, length and percentage of grades, percentage of trucks and buses
- o To estimate capacity during work zone lane closures: total number of lanes, number of lanes closed, desired percentile value from the distribution of observed capacities

Output

- 0 Capacity
- o Queuing characteristics: maximum queue length, time to normal flow, queue length at the end of each hour, total vehicle delay, average delay per delayed vehicle, average delay per approach vehicle, percentage of vehicles delayed

Computer Needs

- o FREWAY was written for IBM-compatible microcomputers with DOS 2.0 operating system. The program requires 62 K RAM.

Availability

o Available from: McTRANS
University of Florida
512 Weil Hall
Gainesville, FL 32611
904-392-0378

See page B-33 in Appendix B for more detailed information.

TRAFFIC SIMULATION MODELS:
DELAY

Analysis Capabilities

- Estimate queueing characteristics resulting from freeway bottlenecks caused by lane closures during maintenance/construction activities or freeway incidents

Data Requirements

- Capacity flow rates under normal and bottleneck conditions
- Demand flow rates
- Incident duration

Output

- Measures of queueing conditions (total delay in vehicle-hours, time to normal flow, maximum number of vehicles in queue, and maximum length of queue in miles)

Computer Requirements

- DELAY (referred to in MCTRANS catalog as Freeway Traffic Congestion) is a spreadsheet that uses LOTUS l-2-3 and runs on IBM-compatible microcomputers with at least 128K of memory

Availability

- Available from: McTRANS
  University of Florida
  512 Weil Hall
  Gainesville, FL 32611
  904-392-0378

See page B-33 in Appendix B for more detailed information.

TRAFFIC SIMULATION MODELS: FREQ

Analysis Capabilities

o Estimate operating conditions (speeds, flows, densities, queues, delays), fuel consumption, and vehicle emissions on a section of a directional freeway over a specified period of time

o Estimate impacts of various freeway traffic management strategies (lane closures, ramp closures, ramp metering, priority entry, and priority lane control) on freeway operating conditions

0 Optimize ramp metering rates

Data Requirements

o Roadway Characteristics: link lengths, number of lanes, capacities, ramp locations and capacities, design speeds, grades, and truck percentages for the freeway and alternative route

o Traffic Demand: Ramp origin-destination matrix and existing traffic on alternative route for each time slice (exit and entrance ramp volumes can be used to estimate the ramp origin-destination matrix using the SYNPD2 module in FREQ)

o Optional inputs to adjust program parameters (vehicle occupancy, speed-flow curves, vehicle emission data, etc.) as desired by the user

Output

o Performance summaries of MOEs on freeway and alternative route by link and by time slice (cumulative summary of MOEs also provided)

o Optional outputs include contour diagrams of speeds, densities, queue lengths, fuel consumption, emissions, and noise

Computer Needs

o Will run on mainframe (FREQ9) or microcomputer (FREQ8PC)

o FREQ8PC version requires an IBM-PC compatible computer with a minimum of 512K RAM, a math coprocessor, and a hard drive with at least 2M of free disk space available

Availability

o Available from: Institute of Transportation Studies
109 McLaughlin Hall
Berkeley, CA 94720
415-642-3585

See page B-39 in Appendix B for more detailed information.

TRAFFIC SIMULATION MODELS: TRAFLO

Analysis Capabilities

- o Estimate operating conditions (speeds, flows, densities, queues, delays), fuel consumption, and vehicle emissions over a section of a freeway corridor (freeways and surrounding arterial street system) or urbanized region over a specified period of time

- o Estimate impacts of various freeway traffic management strategies (lane closures, ramp closures, ramp metering, priority entry, and priority lane control) and/or TSM techniques on surrounding arterial street system

Data Requirements

- o Roadway Characteristics: link lengths, number of lanes, capacities, ramp locations and capacities, free-flow speeds, and truck percentages for the freeway(s); similar data along with intersection control characteristics for the arterial street system

- o Traffic Demand: Zonal origin-destination matrix or turning percentage and entry volumes for each entry link in the model for each time slice

- o Optional inputs to adjust program parameters (vehicle occupancy, speed-flow curves, queue discharge characteristics, vehicle emission data)

Output

- o Performance summaries of MOEs on freeway(s) and arterial street system by link and by time slice (cumulative summary of MOEs also provided)

Computer Needs

- o Will run on mainframe using VS FORTRAN compiler (microcomputer version undergoing development and testing)

Availability

- o Available from: Systems and Software Support Branch (HTO-23)
  Off ice of Traffic Operations
  Federal Highway Administration
  Washington, DC 20590
  202-366-2186

See page B-39 in Appendix B for more detailed information.

TRAFFIC SIMULATION MODELS:
INTRAS

Analysis Capabilities

- o Microscopic analysis of operating conditions over a section of a freeway corridor (freeways and surrounding arterial street system) over a specified period of time.
- o Estimate impacts of expected traffic pattern changes and proposed traffic management strategies for reconstruction

Data Requirements

- o Roadway (Link) Data: link length, number of lanes, grade, superelevation, radius of curvature, ramp locations, free-flow speeds, and truck percentages for the freeway(s); similar data along with intersection control characteristics (type of control, signal timing settings) for the arterial street system
- o Traffic Demand: Entry volumes (by vehicle type and lane distribution) for each entry link, and turning percentages for each time slice
- o Optional inputs to adjust program parameters (following distance and lane change time, queue discharge characteristics, vehicle emission data)

Output

- o Traffic Performance Summary Tables: delays, densities, speeds, travel miles, volumes, fuel consumption and vehicle emissions for freeway links; similar output with cycle failures and degree of saturation for the arterial street system (provided by link and overall for each time slice and for the entire simulation period)
- o Optional Outputs: digital plots of vehicle time-space trajectories, contour maps of speeds, volumes, densities, delays, headways, and travel times; direct comparisons and statistical tests of MOE values from separate simulation runs

Computer Needs

- o Will run on mainframe computer using ANSI FORTRAN compiler (this model will eventually be replaced by a model called FRESIM which is currently undergoing development and testing)

Availability

- o Available from: Systems and Software Support Branch (HTO-23)
  Office of Traffic Operations
  Federal Highway Administration
  Washington, DC 20590
  202-366-2186

See page B-39 in Appendix B for more detailed information.

TRAFFIC SIMULATION MODELS:
NETSIM

Analysis Capabilities

- o Microscopic analysis of traffic operations over time throughout an urban arterial network
- o Estimate the impacts of traffic volume changes during reconstruction or the impact of major and minor TSM improvements (parking and turning controls, changes in intersection control, real-time surveillance and control systems, etc.) upon traffic operations

Data Requirements

- o Roadway (Link) Data: link length, number of lanes and lane types, grades, channelization, capacities, speeds, queue discharge rates, lost times, pedestrian volumes, traffic volumes, truck percentages, turning percentages, bus characteristics, and traffic surveillance characteristics; changes can be made to these data within the simulation to represent temporary conditions
- o Intersection (Node) Data: type of intersection control, signal control characteristics (cycle lengths, phase sequences and durations)

Output

- o Traffic Performance Summary Tables: travel, delay, stops, speeds, queues, link occupancies, degree of saturation, cycle failures, fuel consumption, and vehicle emissions for each link and for entire network, at several points in time and for the entire simulation period

Computer Needs

- o Mainframe or Microcomputer versions available
- o Microcomputer version requires IBM-PC compatible computer with 366k or greater memory and DOS version 2.0 or later. A math coprocessor will enhance program execution

Availability

- o Available from: McTRANS
  University of Florida
  512 Weil Hall
  Gainesville, FL 32611
  904-392-0378

See page B-48 in Appendix B for more detailed information.

TRAFFIC SIMULATION MODELS: PASSER-IV

Analysis Capabilities

- Estimate distribution of corridor traffic demands to freeway and alternative routes based on equilibrium traffic assignment using piece-wise linear relationships between travel time and volume/capacity ratio
- Estimate impacts of major changes in freeway or alternative route capacities during reconstruction upon distribution of corridor traffic demand

Data Requirements

- Roadway (Link) Data: link length, number of lanes, speeds, and capacities for the freeway; same data plus traffic signal densities for the alternative routes
- Total freeway corridor traffic demand

Output

- Table of Results: equilibrium travel time, system volume/capacity ratio, volumes assigned and resulting volume/capacity ratio for the freeway and each alternative route

Computer Needs

- Written in FORTRAN. Can be used on mainframe or microcomputer

Availability

- Documentation: Texas Transportation Institute
  The Texas A&M University System
  College Station, TX 77843
  409-845-I 734

See page B-52 in Appendix B for more detailed information.

TRAFFIC OPTIMIZATION MODELS: SOAP

Analysis Capabilities

- o Optimize cycle length, phase sequence, and phase durations for an isolated, fixed-time (or approximated traffic-actuated) signalized intersection (up to 8-phases) in steady-state traffic conditions
- o Estimate the impacts of changes in approach volumes (due to reconstruction) or the mitigating effect of signal timing changes upon traffic operations at the intersection

Data Requirements

- o Approach Data: traffic volumes, turning movements, truck percentages, and approach capacities or number of lanes
- o Intersection (Node) Data: existing signal timing characteristics (if to be evaluated), minimum green durations

Output

- o Traffic MOEs: delay, saturation ratio, queue length, stops, fuel consumption, left-turn conflicts
- o Optimized Signal Timing Settings: phasing sequences and durations, cycle length
- o Comparison Reports (Optional): direct tabular comparisons of delay and fuel consumption for alternative runs

Computer Requirements

- o Can be run on Mainframe or Microcomputer
- o Microcomputer version (SOAP84) can be run on IBM-PC compatible (DOS 2.0 or later) and Apple II + /CPM computers

Availability

o Available from: McTRANS
University of Florida
512 Weil Hall
Gainesville, FL 32811
904-392-0378

See page B-57 in Appendix B for more detailed information.

TRAFFIC OPTIMIZATION MODELS: TRANSYT-7F

Analysis Capabilities

- o Optimize fixed-time traffic signals for an urban arterial network, based on the minimization of delays and stops at intersections for steady-state traffic conditions
- o Estimate impacts of major TSM improvements at intersections and along arterials upon operating conditions (delays, stops, speeds, fuel consumption) throughout the arterial network

Data Requirements

- o Roadway (Link) Data: link length, number of lanes, capacities,traffic volumes, fraction of volume coming from each upstream feeding link
- o Intersection (Node) Data: signal control characteristics (cycle length, number of phases, phase sequences, phase durations)
- o Calibration Data (Optional): flow/speed multipliers, platoon dispersion factors

output

- o Traffic Performance Summary Tables: degree of saturation, travel time, delays, stops, queue lengths, and fuel consumption by link and for the entire network
- o Signal Timing Tables: phase intervals and offsets
- o Optional Outputs: flow profile plots, time-space diagrams

Computer Needs

- o Mainframe or Microcomputer versions available
- o Microcomputer version requires IBM-PC compatible computer, DOS 2.0 or later, two floppy disk drives (or hard drive) and 132-character printer. A math coprocessor is recommended to speed program execution.

Availability

- o Available from: McTRANS
  University of Florida
  512 Weil Hall
  Gainesville, FL 32611
  904-392-0378

See page B-57 in Appendix B for more detailed information.

TRAFFIC OPTIMIZATION MODELS: SIGOP III

Analvsis Capabilities

- o Optimize fixed-time traffic signals for an urban arterial network, based on the minimization of delays, stops, and queues at intersections for steady-state traffic conditions
- o Estimate impacts of traffic volume changes due to reconstruction or the effectiveness of major TSM improvements upon operating conditions (delays, stops, speeds, etc.) throughout the arterial network

Data Requirements

- o Roadway (Link) Data: link length, number of lanes, turning bays, truck percentages, speeds, headways, lost time, traffic volumes and turning percentages
- o Intersection (Node) Data: signal control characteristics (cycle lengths, phase sequences, phase timings, and offsets)

Output

- o Traffic Performance Summary Table: Speeds, delays, stops, queues, fuel consumption, vehicle emissions, and degree of saturation for each link and for the total network
- o Optimized Signal Timings: cycle length, phase durations, and offsets

Computer Needs

- o Mainframe and Microcomputer versions available
- o Microcomputer version requires IBM-PC compatible computer. A math coprocessor will speed program execution.

Availability

- o Available from: McTRANS
  University of Florida
  512 Weil Hall
  Gainesville, FL 32611
  904-392-0378

See page B-57 in Appendix B for more detailed information.

TRAFFIC OPTIMIZATION MODELS:
PASSER II-87

Analysis Capabilities

- o Coordinated analysis to maximize progression bandwidth and minimize vehicular delay for fixed-time traffic signals along an urban arterial in steady-state traffic conditions
- o Estimate impacts of signal timing changes on travel times, speeds, and delays along an arterial
- 0 Simulation of existing signal timing plans along an arterial

Data Requirements

- o Approach Data: speeds, traffic volumes, capacities, turning movements
- o Intersection (Node) Data: acceptable cycle lengths and phase sequences, minimum allowable green times, distances between intersections

Output

- o Optimum (within constraints) cycle length, phase sequences, phase durations
- o Progression bandwidths, bandwidth efficiency and attainability, average progression speed
- o Intersection level of service, saturation ratio, stops, delay, fuel consumption, and time-space diagrams

Computer Needs

- o Available in Mainframe and Microcomputer versions
- o PC version requires IBM-PC compatibility w/ DOS version 2.0 or later

Availability

- o Available from:

McTRANS
University of Florida
512 Weil Hall
Gainesville, Fl 32611
904-392-0378

Texas Transportation Technology Tranfer
Technology Resource Center
Texas Engineering Extension Service
The Texas A&M University System
College Station, TX 77843-8000
409-845-4369

See page B-57 in Appendix B for more detailed information.

TRAFFIC OPTIMIZATION MODELS:
MAXBAND-86

Analysis Capabilities

- Optimization of fixed-time traffic signals in urban arterial or grid networks using an integer programming procedure to maximize bandwidth

- Estimate impacts of signal timing changes on travel times and speeds along an arterial or network

Data Requirements

- Roadway (Link) Data: lengths, speeds, trafficvolumes, capacities, turning movements (optionally, one may input green times for each signal phase in lieu of traffic data)

- Intersection (Node) Data: acceptable cycle lengths, phase sequences (including left-turn patterns), and durations; basic spatial relationships between intersections

Output

- Inbound and outbound bandwidths, optimum cycle length, phase lengths and sequences, offsets, progression travel times and speeds on links

Computer Needs

- Mainframe version written in FORTRAN

Availability

- Available from: Systems and Software Support Branch (HTO-23)
  Office of Traffic Operations
  Federal Highway Administration
  Washington, DC 20590
  202-366-2186

See page B-57 in Appendix B for more detailed information.

APPENDIX B

DETAILED REVIEWS OF AVAILABLE ANALYSIS TOOLS

This appendix provides detailed reviews of available analysis tools with potential application to the travel impact evaluation process for major highway reconstruction projects. The reviews provide an assessment of the analysis tools in eight areas:

1. Application and purpose--i.e., what the analysis tool was designed to do and how it was intended to be used, what type of issues it was designed to analyze
2. Use--i.e., how the tool could be used in the reconstruction project travel impact evaluation process
3. Limitations--i.e., constraints on the use of the tool
4. Data Requirements
5. Typical Output
6. Advantages and Disadvantages--i.e., ease of use, knowledge or training required, level of effort required to satisfy the data requirements and to actually use the tool, level of accuracy and detail of output, sensitivity of the analysis to key issues in the reconstruction context
7. Success at Forecasting Travel During Actual Reconstruction--i.e., effectiveness of previous applications of the tool for planning reconstruction projects
8. Appropriateness for Reconstruction Project Travel Impact Evaluation-- i.e., overall assessment of how effectively the tool could be used in the reconstruction project travel impact evaluation process

NETWORK-BASED HIGHWAY AND TRANSIT PLANNING MODELS

Network-based highway and transit planning models can play a valuable role in evaluating the corridor-wide travel impacts of a major highway reconstruction project. They provide analysis capabilities in part or all of the traditional four-step travel demand modeling process: trip generation, trip distribution, mode split, and traffic assignment. These capabilities are particularly important when corridor-level issues must be addressed, such as when the capacity reductions on the highway being reconstructed may cause significant traffic diversion to alternative routes and modes in the corridor. Network-based planning models may be used to describe travel patterns before reconstruction and, particularly, to identify the origins and destinations of the current users of the highway being reconstructed. Knowledge of the current users is important in order to identify the alternative routes and modes that are likely to be impacted and that may require capacity enhancements. Network-based planning models also have important applications in evaluating the changes in travel patterns that might result from alternative traffic management plans for a project.

A reconstruction project may cause changes in any of the four aspects of urban travel patterns:

1. The number of trips produced in or attracted to zones affected by the reconstruction project
2. The origin-destination patterns of trips that traversed the corridor prior to reconstruction
3. The modal split of trips in the corridor
4. The assignment of trips among alternative routes in the corridor

Fears of undesirable changes in trip generation or distribution patterns are a major reason for the opposition to reconstruction projects by affected business communities. Therefore, it may be important to predict whether or not trip generation and distribution patterns would change. The more commonly used approach has been to estimate the travel impacts based upon the assumption that trip generation and distribution patterns would not change. In fact, it was either explicitly or implicitly assumed in the planning for the reconstruction projects in Pittsburgh, Boston, Philadelphia, Detroit, and Minneapolis (as discussed in Appendix C) that trip generation and distribution patterns would not change.

Changes in mode split in the corridor are typically desirable; one of the principal strategies that has been employed to mitigate travel impacts is to improve HOV services in the corridor in order to increase average vehicle occupancy and thereby maintain the same number of person trips in the corridor, but in fewer vehicles and at a better level of service. Previous experiences in Pittsburgh, Boston, and Detroit indicate that the actual changes in modal split during reconstruction have been small, although important nonetheless. From an analysis standpoint, however, it is likely to be extremely difficult, given the capabilities of available analysis tools, to predict with any accuracy the incremental changes in mode split that may result from a reconstruction project. It is unlikely that available analysis tools could provide information that would be sufficiently reliable to influence decisions about the types and magnitude of improvements in HOV services. Therefore, sound judgment should be used in determining the cost- effective level of effort to expend in evaluating changes in mode split. (The approach used in Boston, to implement improvements with the flexibility to discontinue those that were not well used, may be a wiser strategy.)

Changes in the allocation of trips in the corridor--away from the highway being reconstructed and to alternative routes--have been the most commonly observed response of motorists to major highway reconstruction projects. For cases in which significant diversion to alternative routes is likely, it is important to estimate how much traffic will divert and to evaluate which alternative routes diverted traffic will use. Therefore, analysis tools, such as network-based planning models, which have traffic assignment analysis capabilities, are very important. Accurate estimates of the changes in traffic assignments among alternative routes in the affected corridor are vital to the identification of cost-effective improvements on alternative routes to mitigate the adverse impacts of the reconstruction project.

In Detroit, for example, the regional transportation model was used to evaluate alternative traffic management plans for the reconstruction of the Lodge Freeway. The model was used to estimate percentage changes in traffic assignments to alternative routes and percentage changes in travel times in the corridor, based upon the assumption that trip generation and distribution patterns would not change. The estimates from the model influenced decisions regarding improvements to alternative routes and modes in the Lodge Freeway corridor.

Applications of network-based planning models in a reconstruction context have been limited, and in those locations where they have been applied, there has been no formal comparison or documentation of how the estimates from the model compared with the actual travel impacts during reconstruction. Therefore, at the present time, there is no objective basis for drawing conclusions about the reliability with which network-based planning models could be used in evaluating the travel impacts from reconstruction projects. It would appear that network-based planning models would be most useful in evaluating corridor-level issues and impacts, which is something that most other analysis tools, except perhaps quick-response estimation techniques and certain network-based traffic simulation models, could not do.

Several network-based travel demand modeling packages are available on microcomputer, any of which can be used in planning for a reconstruction project. These packages can be most useful if a travel demand model is being maintained by the regional planning agency. If a recently validated travel demand model is not available for the urban area, it may not be a good use of time or resources to develop a model simply for the purpose of planning a reconstruction project, unless the project is particular large. Many urban areas use a mainframe, regional transportation model. The mainframe model could be used directly. However, these microcomputer packages can be used effectively in conjunction with the mainframe model. Most of the microcomputer packages provide for downloading of network and trip generation data from a mainframe package. The microcomputer packages can evaluate a large number of alternatives in a short period of time at a reasonable cost.

There are several network-based microcomputer packages available on the market. Most of these are described in the current edition of the Microcompters in Transportation Software and Source Book (2)

Application and Purpose

Most network-based packages use the traditional four-step travel demand modeling process. The primary purpose of the four-step process is for evaluation of land-use and transportation system alternatives. Traffic assignments are the most widely used product of the total process, and are the most relevant for evaluation of the impacts of a reconstruction projects. Traffic assignment is the process of determining the route or routes of travel and allocating the zone-to-zone trips to these routes. A transportation network and trip table are needed to run a traffic assignment.

Traffic assignments have the following applications:

- o Developing and testing alternative transportation systems or projects
- o Establishing short-range priority programs for transportation facility development
- o Analyzing alternative locations for facilities
- o Providing input and feedback for other planning tools
- o Developing design volumes

The output of a traffic assignment is an estimate of the number of trips or traffic volume for each link of the transportation network. These may be 24-hour highway vehicle trips or peak hour highway vehicle trips, 24-hour transit person trips or peak hour transit person trips.

Use

Network-based models can be used in several ways in the travel impact evaluation process for reconstruction projects. The primary application would be to estimate the changes in corridor travel patterns and traffic volumes resulting from alternative traffic management plans.

Travel impacts can be reported in terms of changes in assigned volumes, travel impedances, and link speeds. The models analyze the travel impacts not only on the highway being reconstructed but also on alternative routes in the corridor. The following procedures can be used to evaluate the impacts of a highway reconstruction project:

- o Procedure to collect existing data such as existing network data including link files and nodes files, zonal trip ends, and description of reconstruction area
- o Procedure to redefine the existing study area b modifying or deleting a reconstruction route (i.e., reducing capacities and/or speeds)
- o Procedure to run trip distribution to obtain trip tables
- o Procedure to analyze mode split using either a logit model or diversion curves
- o Procedure to perform a subarea analysis (which might be defined as an impact area surrounding the reconstruction area)
- o Procedure to determine traffic volumes using various assignment techniques

- o Procedure to perform a select link analysis (which identifies the origin and destination of all trips traversing a specified link)

Limitations

Since the main purpose of planning models is for evaluation of land-use and transportation system alternatives, the level of accuracy associated with assigned volumes may be less than for traffic simulation or optimization models. Network-based planning models are validated for a base year by comparing assigned volumes with ground counts. It is difficult to establish a minimum acceptable level of model accuracy without an understanding of how assignments produced by the model will be used. When using assignments from any network-based planning model for reconstruction planning, the analyst needs to be sensitive to the level of accuracy associated with those assignments. Assignments results may be acceptable for some applications but not for others.

Data Requirements

If a validated regional transportation model is available on a mainframe the data input can be simplified by downloading the highway network and the production and attraction data from the mainframe computer. If a validated model is not available, the input step can require considerable effort. Some data requirements for network-based models include:

- o A highway network: link and zone node information; travel time or link distance and speed; number of lanes and/or capacity; turn penalties; base year ground counts
- o Zonal productions and attractions or zonal data: number of dwelling units; number of retail/non-retail employees; average household income or autos per household
- o Friction factors for trip distribution
- o Changes to the network or link data as a result of the reconstruction project

Typical Output

Various output reports are produced by the planning software packages. The The following outputs might be useful for evaluating the impacts of highway reconstruction:

- o Report of traffic assignment results in terms of updated assigned volumes, and link speeds on the highway being reconstructed and on alternative routes in the corridor
- o A ground count comparison report, providing summary statistics which are useful in evaluating how well assigned volumes match counted traffic volumes
- o Reports for select link analysis and subarea analysis
- o Turning Movements
- o Trip tables
- o Displays and plots of network attributes and assignment results

<u>Advantages and Disadvantages</u>

The major advantage of any microcomputer, network-based planning model is that a large number of alternatives can be tested with a modest amount of analyst time. If a more detailed analysis is required, several software packages can provide a select link analysis or subarea analysis for later refinement using NCHRP 255. Traffic impacts are identified for all alternative routes in the corridor not simply the highway under construction.

The disadvantage of any microcomputer network-based planning model is that a great deal of effort is required to prepare a validated model. If a validated model is available on a mainframe computer, this is not a problem because most of the data required can be downloaded to the microcomputer. If a validated model is not available, then the resources and time required to prepare a model need to be carefully evaluated before making a decision to use a network-based planning model.

<u>Success at Forecasting Travel During Actual Reconstruction</u>

As of this report, limited documentation on the application of microcomputer analysis tools to evaluate the travel impacts of highway reconstruction exists.

<u>Appropriateness for Reconstruction Project Travel Impact Evaluation</u>

Network-based models are an appropriate planning tool to use particularly during the early stages of a reconstruction project. Changes in travel patterns and traffic volumes on all facilities impacted by the project can be identified. A wide variety of alternatives can be evaluated quickly at a modest cost. Select link analysis and subarea studies can be prepared for further refinement using NCHRP 255 procedures.

QUICK-RESPONSE ESTIMATION TECHNIQUES

Quick-response estimation techniques are simplified analysis tools for travel demand modeling that were designed as less time-and data-intensive alternatives to network-based planning models. Quick-response estimation techniques include both manual and computer-aided tools which produce reasonably sensitive outputs with a relatively small investment of time and effort. Quick-response estimation techniques may be an appropriate tool in the evaluation of reconstruction projects for which corridor-wide impacts must be considered but which are not sufficiently large to justify the effort that would be required to use network-based planning models.

Quick-response estimation techniques are available for all of the traditional steps in the travel demand modeling process: trip generation, trip distribution, mode split, and traffic assignment. As indicated in the discussion of network-based planning models, changes in trip generation and trip distribution may be politically unacceptable. Quick-response tools could be used to evaluate whether such changes might occur. However, it has been more common to evaluate the changes in traffic assignment among alternative routes in the affected corridor based on the assumption that trip generation and distribution patterns would not change. Several quick-response estimation techniques are available for traffic assignment analysis.

The use of network-based planning models to evaluate changes in mode split is generally not justified because the magnitude of changes is so small. The simplified quick-response techniques that evaluate changes in mode split due to changes in cost or service characteristics may be more appropriate.

Six quick-response tools are reviewed: NCHRP 187 manual techniques, which include procedures for all steps in travel demand forecasting; NCHRP 255 techniques for traffic assignment; two inverse assignment procedures LINKOD and TRIPS, which estimate or refine origin-destination trip tables from link volume and turning movement counts; and two pivot-point mode split analysis techniques MODE CHOICE and RTD Pivot Point Logit Model, which estimate changes in mode split.

NCHRP 187 Manual Methods

Application and Puroose

NCHRP 187 "provides simplified manual techniques and transferable parameters that can be used as viable alternatives to the more costly, data-intensive computer models" (8) Simplified manual techniques are provided for trip generation, distribution, mode choice, traffic assignment, automobile-occupancy characteristics, capacity analysis, time-of-day distribution, and development density versus highway spacing relationships. The latter three techniques would have little application in evaluating the travel impacts from reconstruction projects and, therefore, are not discussed. For many of the data requirements, transferable parameters are provided that can be used in lieu of local data, thereby minimizing the data collection effort to use the techniques.

Use

NCHRP 187 provides quick-response estimation techniques for trip generation, trip distribution, mode choice, automobile-occupancy characteristics, and traffic assignment that may be useful in evaluating the changes in travel patterns resulting from major highway reconstruction projects. These techniques can analyze and refine output from a regional transportation model, but the user should realize that for a regional analysis with a large number of analysis areas, computer methods may be more appropriate. If the user wants to perform regional sketch-planning with perhaps 20 to 25 analysis areas, then the NCHRP 187 techniques are appropriate.

The trip generation procedure provides generalized trip generation rates that can be used to estimate the number of trips produced in or attracted to a zone based upon the character, intensity, and location of land-use activity. The procedure may be too generalized to be sensitive to the minimal changes in trip generation that may result from a reconstruction project.

The trip distribution procedure uses a simplified gravity-model-based approach to produce an origin-destination trip table that contains estimates of the number of trip interchanges between all zones in the network. By identifying these interchanges, one can determine the origins and destinations of the traffic using the proposed reconstruction segment. NCHRP 187 identifies three applications of its trip distribution procedures: region-wide, corridor, and site analyses. Site analysis, which applies to a special generator (i.e., special events center, amusement park, etc.), has no application to reconstruction projects and therefore will not be discussed. Region-wide analysis could give a broad picture of the origins and destinations of the traffic using the highway being reconstructed. Region-wide analysis produces a set of distributions which is a useful starting point for the more refined corridor analysis. In the corridor analysis, the user has the choice of using an established trip table or constructing a new one using a revised set of zones (which is more detailed than for region-wide analysis). The corridor analysis would be appropriate for determining the shorter trips (intrazonal trips which are disregarded in the region-wide analysis) which would be using the highway being reconstructed.

The mode-choice analysis procedure could be used to estimate the changes in mode split that might result from any improvements in HOV service that are included as part of the traffic management plan for a reconstruction project. The NCHRP 187 mode-choice analysis technique can be used to estimate the changes in mode split resulting from changes in transit and auto system operating characteristics. The automobile-occupancy characteristics technique is used to translate the auto person-trip estimates from the mode-choice analysis into estimates of the number of vehicle trips between each pair of analysis zones.

NCHRP 187 provides three techniques for traffic assignment: (1) traditional traffic assignment, which is based on an all-or-nothing assignment (all trips between the two zones take what the analyst believes to be the shortest, most logical route); (2) traffic generation and decay, which estimates the traffic impacts of a proposed traffic generator; and (3) traffic diversion/traffic shift, which estimates the changes in the assignment of traffic among routes in a corridor resulting from changes in the capacity of one route. The simplified, traditional traffic assignment technique could be used to compare corridor-wide volumes for alternative traffic management plans. The traffic diversion/traffic shift technique could also be used to estimate traffic diversion from the highway being reconstructed to alternative routes in the corridor.

Limitations

The principal limitation of the NCHRP 187 techniques is the same as its principal advantage: maximum use is made of generalized, transferable parameters. The advantage is that the use of transferable parameters minimizes the input data requirements. The limitation is on the level of accuracy of the results. It is likely that the trip generation and trip distribution procedures would not be sufficiently sensitive to evaluate the minimal changes in patterns that may result from a reconstruction project. Another limitation of the trip distribution procedure is that for a large number of zones, several modes of travel, and several trip purposes, the manual method becomes time consuming. The mode-choice analysis procedure can be used only where scheduled routes exist and is not recommended for application to demand-responsive or special (e.g., express bus) services.

Data Requirements

As stated earlier, the principal advantage of the NCHRP 187 techniques is that data requirements have been kept to a minimum through the provision of transferable parameters. The user is urged to use as much location-specific data as possible to avoid inaccuracies that might be introduced from using the transferable parameters provided in NCHRP 187; however, this defeats the intention of the methods which is to provide quick-response estimates of the order of magnitude of impacts. The output from a regional transportation model may be used as input to the NCHRP 187 manual techniques, but the user will first need to reduce the amount of detail in the output. That is, it may be necessary to reduce the number of zones by either reducing the size of analysis region or by combining several smaller zones. As previously stated, these techniques are intended to provide quick response; therefore, the amount of input should be fairly concise and the techniques should not be used for extremely detailed analyses.

Data requirements for the trip generation procedures include the land-use and socio-economic characteristics generally used for area-wide planning and site-specific characteristics used in land-development analysis. The procedures allow some variation in data requirements based on data availability, level of analysis required, and time available. Other data necessary include number of households by income category and/or average autos per household, cordon count and total regional auto driver trips, and for each zone, total employment, retail employment, number of households.

The trip distribution procedures have the following data requirements:

- o A map of the study region showing the layout of the zones and their centroids; boundary limits of the CBD, central city, and suburban subregions; and major freeways and arterials
- o Production and attraction trip ends for each zone and trip purpose, which can be obtained from the quick-response trip generation procedure or from a regional transportation model
- o A travel time/distribution factor matrix, which can be computed from airline distances between zones or which can be based upon accessibility indices from a regional transportation model

The data requirements for the mode choice procedure vary depending on previous work done for the study area. The user should take advantage of any models and values that are available for a specific study area, but for those areas with a minimal history of transportation planning, default values are provided. The data requirements include:

highway airline distance, transit airline distance, transit fare, auto operating cost, attraction-end parking cost, and average highway speed.

The automobile-occupancy characteristics procedure requires only an estimate of the urbanized area population and the land-use at the trip destination along with the generalized automobile-occupancy rates provided in NCHRP 187.

The traffic assignment procedures require an origin-destination trip table and a map of the highway network.

Typical Output

The trip generation procedures provide estimates of the number of trips to and from zones for three trip purposes: home based work, home based non-work, and non-home based. The trip distribution procedure produces an origin-destination trip table. The mode-choice analysis procedure produces an estimate of person trips for three modes (transit, shared ride, drive alone). The automobile-occupancy characteristics procedure translates the estimates of auto person-trips from the mode-choice analysis into an estimate of the number of vehicle trips. The traffic assignment procedures provide estimates of vehicle volumes on alternative routes in the corridor.

Advantages and Disadvantages

The principal advantages of the NCHRP 187 quick-response estimation techniques are that they are relatively easy to use, have minimal data requirements, and require low to moderate level of effort. The data requirements are fairly easily satisfied. The principal disadvantage is that the sensitivity to location-specific conditions is limited by the extensive use of generalized, transferable parameters. When high degrees of accuracy are required, the procedures may not be appropriate.

Success at Forecasting Travel During Actual Reconstruction

The Southwestern Pennsylvania Regional Planning Commission (SPRPC) used NCHRP 187 procedures in the early stages of planning for the reconstruction of I-376, Penn Lincoln Parkway East, in Pittsburgh. A detailed review of this application is presented in Appendix C.

Appropriateness for Reconstruction Project Travel Impact Evaluation

NCHRP 187 techniques can be appropriately used in the reconstruction project travel impact evaluation process. The procedures were designed to give quick-response estimates for corridor-wide assessments or order-of-magnitude evaluations, and can be used effectively within that context.

NCHRP 255 Traffic Assignment Refinement Techniques

The purpose of the NCHRP 255 traffic assignment refinement techniques is to improve upon the assignments produced by the four-step travel demand modeling process (9) These techniques include: the screenline refinement procedure, which is most useful for analyzing changes in corridor capacity; select link analysis, which estimates origin-destination travel patterns for trips traversing specified links; and the detailed network analysis procedures, which are methods for estimating trip volumes for more detailed networks.

Nearly all system-level traffic assignments require that further refinement take place prior to using the assigned volumes for highway project planning and design. The same procedures can be used in a variety of ways to support the planning associated with a reconstruction project. The techniques are clearly explained in NCHRP 255 and can be accomplished manually or with the assistance of computer programs,

Application and Purpose

The screenline refinement procedure uses relationships between base year traffic counts and future year capacities to adjust traffic crossing a screenline. The procedure includes two types of adjustments. The first type adjusts the future year link volumes according to the amount of deviation between the base year traffic counts and the base year assignment. The second type of adjustment is based on relationships between base year traffic counts and future year link capacities.

Select link analysis uses a computer program, such as LINKUSE of PLANPAC or UROAD of UTPS, to identify the origin-destination trip patterns for trips traversing selected links or trips moving between selected zone pairs. This procedure can be used to refine base or forecast year traffic assignments to reflect subsequent changes in the capacity of a facility represented by a link or group of links in a network. The analyst identifies which origin-destination trip interchanges from the trip table pass through a link or links using the select link analysis option of a assignment program. These trips are then manually assigned to the modified network, giving a clearer picture of trip movements and volumes in the vicinity of the selected link.

The detailed network analysis is recommended when the facility to be reconstructed can be defined as part of a subarea. Two related methods are presented: subarea windowing and subarea focusing. Subarea windowing requires defining the study area within a cordon line and developing a more detailed network within the window for further study. Because the subarea window is extracted from the original network, subsequent analyses can be performed manually. Subarea focusing retains the entire regional or subregional highway network and trip table; however, zonal and network data are developed to a greater degree of detail within the subarea and aggregated to a lesser degree of detail outside the subarea. Typically, a new assignment is run and the resulting detailed network assignment is then refined in a manner similar to a system-level assignment. NCHRP 255 provides procedures to accomplish the detailed network assignment manually if the subarea is small.

<u>Use</u>

The traffic assignment refinement techniques can be used to evaluate changes in traffic volumes and travel patterns in the area surrounding the highways being reconstructed.

The following modified screenline refinement procedure is suggested:

- o Apply screenline procedure to original base or future year network
- o Repeat procedure using revised network (capacity changes)
- o Compare assigned volumes
- o Perform reasonableness checks for volume/capacity ratios of parallel facilities
- o Make final adjustments

This procedure will provide reasonable adjustments of a traffic assignment due to changes in the link capacities of parallel facilities crossing a common screenline. In most cases, the effect will be to spread the impacts over several parallel facilities. If the analyst feels that the impacts of the lane closure on the highway being reconstructed will be more isolated, the select link analysis procedure may provide better results.

The following select link procedure is suggested:

- o Refine assignment from original base or future year network
- o Modify base or forecast year network (capacity/speed changes)
- o Identify links for analyzing network change
- o Run select link analysis program
- o Identify competing paths and compute new travel times
- o Perform volume adjustments
- o Make final check of volume/capacity ratios

A network change will generally result in a change in travel time for various travel paths. The analyst can estimate a revised travel time for traffic impacted by the network change. For a capacity change on a specified link, the previous link travel time is generally proportioned up or down by some fraction of the amount which the capacity has decreased or increased. Judgment is used to determine an appropriate change.

The following detailed network procedure is suggested:

- o Define study area
- o Define new zone system and highway network
- o Estimate or compute revised trip table for detailed highway network
- o Estimate or compute assigned trips to revised network
- o Refine trip assignment within study area

The study area needs to be chosen with care. NCHRP 255 discusses several factors that need to be considered so that an optimum balance is achieved between computational efficiency and the reliability of the results.

Limitations

The screenline refinement procedure typically adjusts all volumes crossing the screenline. Therefore, it is not useful in situations where only one or two links are in need of refinement. The procedure is limited to situations where reasonable screenlines can be constructed across parallel facilities. Accuracy is lost when nonparallel facilities (e.g., diagonal roads) cross the screenline. The most accurate results are obtained when base-year traffic counts, a base-year assignment, and a future-year assignment are available. The procedure is less accurate if base-year counts are not available. This procedure assumes no change in trip generation, trip distribution, or total corridor volume as a result of a change in link capacity. This limitation is not a significant problem for analyzing minor to moderate link changes. Major changes, which could result in a reorientation of the origins and destinations of trips, should not be evaluated using this procedure.

The primary limitation of the select link analysis is the need to have a select link program included in the computer package used for regional travel demand modeling. A select link analysis output needs to be compared with base-year traffic counts or origin-destination studies to establish its reasonableness. The usefulness of the procedure is diminished if adequate base-year counts are not available. In most cases, select link analysis does not explicitly consider link capacities on a network. Trips are redistributed based on changes in travel paths rather than on the basis of available capacity. Finally, because the network typically does not include all collectors and local streets, the results of select link analysis need to be refined if collector and local street volumes are required.

The detailed network analysis is most valid in cases where base-year traffic counts are available for the links on which the traffic forecast is desired. When-base year counts are not available, the accuracy of the traffic forecast is diminished. It may be difficult to develop a revised trip table for external trips without using select link analysis. In most cases, detailed network analysis does not explicitly consider link capacities on a network. Volumes are redistributed based on the changes in travel paths rather than on the basis of available capacity. This limitation must be considered by the analyst, and the resulting volumes compared against available capacity.

Data Requirements

The following data are used as input to the screenline refinement procedure:

- Highway network (base and future year)
- Base-year traffic counts
- Base-year assignment
- Base-year link capacities

- Future-year assignment
- Future-year link capacities

The following data are used as input to the select link analysis procedure:

- Base-year network
- Base-year trip table
- Specific link(s) for which select link data are to be generated
- Select link computer program

The following data are used as input to the detailed network analysis procedure:

- Base-year network
- Base-year trip table
- Select link data (for manual applications)
- Description of link being reconstructed
- Select link computer software (for computer application)

Typical Output

The output of traffic assignment refinement techniques is simply the refined traffic volume estimates. If changes to the network are made as part of the refinement procedures, the impact of these changes will be included. The procedures are useful even if no network changes are made.

The output of the screenline refinement procedure is an estimate of the traffic volume that would shift in response to a change in the capacity of a link crossing the screenline. The output of select link analysis, is an identification of the origins and destinations of all trips which pass through a link or set of links. The output of detailed network analysis is a refined set of traffic volume estimates for all links included in the subarea.

Advantages and Disadvantages

The advantage of the screenline procedure is that the effects of the change in link capacity are spread over several parallel facilities. Future-year traffic volumes across the screenline are refined based on the relationship between base-year traffic counts, base-year assignments, and future-year link capacities. The disadvantage of the screenline refinement procedure is the need to construct screenlines across the parallel facilities. In those areas where screenlines cannot be constructed, the procedure cannot be used.

The advantage of the select link analysis is its ability to provide the analyst with a clear picture of desired trip movements. Once the computer program is operational, several links can be studied at a modest cost. In addition to refining basic computer assignments, select link analysis can be used to modify the assignment to account for network changes such as changing link capacity, changing the alignment of a facility, or adding links to the network. Similarly, it can assist in performing manual assignments of traffic to a more detailed highway network. The disadvantage of select link analysis is that this technique does not explicitly consider link capacities or volume/capacity ratios. Changes in impedance may not precisely reflect the travel time changes that would occur in a congested facility due to a decrease in capacity. Since traffic volumes are distributed based on reasonable travel paths rather than on the basis of available capacity, the new link volumes should be compared with the link capacities and be manually adjusted. The adjustment process does not follow a standard equation or worksheet. Rather, by closely examining the select link data, the analyst is provided with sufficient background with which to logically perform the traffic assignment refinement.

The advantage of the detailed network analysis is that the procedure can be performed manually or with computer assistance and can take into account factors that are not normally incorporated into a network-based planning model. The disadvantage of detailed network analysis is that a balance must be achieved between the size of the subarea to be studied and the amount of effort required to perform the analysis: the larger the subarea, the better the results, but the more work required. The procedure uses paths based on link impedances rather than link capacity. The refined link volumes should be compared with the link capacities and adjusted manually if necessary.

Success at Forecasting Travel During Actual Reconstruction

Traffic assignment refinement techniques have application for almost any situation where the results of a traffic assignment are used for project development. The techniques can be used for refinement of one or two link volumes or to refine the assigned volumes for a number of links. Although specific examples of the application of the procedures to reconstruction projects are not available, it is expected that the techniques would be used for any project using network-based planning procedures.

Appropriateness for Reconstruction Project Travel Impact Evaluation

The purpose of the traffic assignment refinement techniques is to improve the traffic assignments generated by the network based planning models. With only slight modifications these techniques can be used to evaluate travel impacts on the highway being reconstructed and on the alternative routes in the network. The techniques can be applied manually although computer programs can reduce the manual work required.

The screenline refinement procedure is most useful for analyzing changes in roadway capacity where the impacts can be spread over several parallel facilities.

The select link analysis provides the analyst with origin-destination travel patterns for trips traversing the reconstruction project. This travel pattern information can then be used to estimate the impacts on traffic volumes resulting from changes to the network as a result of the reconstruction project.

The application of detailed network analysis is most appropriate where volume estimates are needed for collector and local streets not included in the original network. The detailed network procedures are the most comprehensive of the techniques discussed. When used in conjunction with computer-based subarea windowing or subarea focusing techniques the procedures can provide detailed volume estimates for all facilities in the vicinity of a reconstruction project and an estimate of how these volumes will change as a result of reconstruction activity.

Inverse Assignment Procedures

Inverse Assignment procedures are used to estimate an origin-destination trip table from observed link volumes. Two packages of this type are LINKOD and TRIPS. LINKOD runs on a mainframe and has the capabilities to produce a trip table from scratch or to refine an existing trip table (10) TRIPS, which is a microcomputer package, is designed to refine an existing trip table and requires much less data entry than does LINKOD (11)

Application and Purpose

LINKOD was developed for estimating an origin-destination trip table for highway traffic in small areas from observed link volumes and (optionally) turning movement counts. It is primarily used for the development and evaluation of short range, subregional traffic improvement plans, and is most effective in the analysis of short range problems, where no significant changes in land use are expected. LINKOD can also be used to refine or update an existing trip table.

TRIPS was developed because a need existed for a less costly and time-consuming methodology to create a trip table than an origin-destination survey or the travel demand modeling procedure. The program was designed to update an existing trip table (either an old trip table for the area or one which is hand calculated).

Use

LINKOD produces a refined trip table which may be used with either traffic assignment or traffic simulation models that require an origin-destination matrix as input. Subroutines of LINKOD are also useful in their own right. SMALD can be used independently to estimate trip tables when volume counts on links inside the area of interest are not available, but the resulting trip tables are considerably less accurate. ODLINK refines the results of actual origin-destination surveys, an initial trip table, or the trip table produced by SMALD, and gives an improved trip table which more closely matches the actual origins and destinations.

TRIPS will update an existing trip table with a relatively small investment in time. This updated trip table can then be used with traffic assignment or traffic simulation models.

Limitations

Inverse assignment procedures are only marginally useful by themselves, but when used along with traffic assignment or traffic simulation models they can assist in providing fairly reliable results. LINKOD may be used where an analysis of proposed traffic improvements is required, and the range of proposed changes in the transportation system is wide enough that some traffic rerouting is likely to occur. The amount of rerouting likely to occur will depend on local conditions and on the magnitude of the reconstruction project.

Limitations of TRIPS are as follows: (1) it responds only to network changes not policy changes, (2) it is recommended for small area analysis using less than 100 links, (3) paths between zones must move through at least one noncentroid node to get accurate results, (4) each link must be used by at least one path, and (5) the number of intrazonal trips should be small because they are disregarded.

Data Requirements

input required for LINKOD includes:

- Zonal data: productions/attractions
- Street operations data: functional classification of the facility, length of link, cycle times
- Observed volumes on links and at intersections

Default values for LINKOD that can be changed by the user include:

- Speed at the desired level of service
- Speed in light traffic
- Link capacity
- Area type (i.e., CBD, residential, rural)
- Number of moving lanes
- Number of pedestrians/minute crossing at an intersection

Data requirements for TRIPS include:

- The chosen number of iterations
- An acceptable percentage of error
- Number of zones
- Number of paths (composed of the different links which could be taken between zones)
- Number of links between zone A and zone **B**
- Path data (origin zone, destination zone, link used, probability of that link being used on that path)

- o An initial trip table
- o Traffic counts for each link (preferably balanced-flow entering intersection equals flow exiting the intersection)

Typical Output

The output for LINKOD consists of (1) a refined trip table, and (2) link data (such as, assigned link volumes, estimated impedance at load, turn links with and without assigned volumes).

TRIPS output consists of a refined trip table.

Advantages and Disadvantages

The main disadvantage of LINKOD is that it is available on mainframe only. The data acquisition can be time intensive if a zonal network and ground counts are not already available. The advantage is that the data requirements are more easily satisfied than for other procedures to estimate a trip table.

The level of effort to use TRIPS is low and the data are easy to acquire. The program itself is fairly easy to use, but since it is still in the development stages, some bugs may exist.

Success at Forecasting Travel During Actual Reconstruction

At this time, neither LINKOD nor TRIPS has been used in a reconstruction project planning process.

Appropriateness for Reconstruction Project Travel Impact Evaluation

Origin-destination information is needed in planning for a reconstruction project in order to identify current users who are likely to be adversely impacted and to design improvements on alternative routes and modes that will serve those users.

LINKOD could either generate a new trip table, if one did not already exist for the area, or could refine an existing trip table for use in other analysis tools.

TRIPS may be an excellent program to update an existing trip table with a modest investment in time and money. The updated table can then be used as input into a traffic assignment or traffic simulation model.

Pivot Point Mode Split Analysis

Pivot point analysis predicts incremental changes in mode choice compared to a "base case" level. The base case may be either an existing condition or the conditions expected to be in existence as a result of factors other than the one being studied, such as population growth and implementation of transportation measures.

MODE CHOICE (12) and RTD Pivot Point Logit Model (13) are quick-response estimation tools for evaluating changes in mode split resulting from changes in modal cost or service characteristics. As indicated earlier, these tools may be the most appropriate procedures for evaluating the changes in mode split resulting from the improvements in HOV services that are incorporated into traffic management plans for major highway reconstruction projects.

Application and Purpose

The Work Trip Mode Choice Estimation Model, or MODE CHOICE, is a spreadsheet-based technique for estimating changes in travel modes for work trips. Estimates are provided for three modes: transit, shared ride (car-pool), and drive-alone. Estimates are based upon certain attributes of the travel population (household income, cars per household) and the travel choices (drive alone, shared ride, transit) available to them. The model was originally calibrated based on data from several cities in a 1979 study by Cambridge Systematics for the Environmental Protection Agency.

The RTD Pivot Point Logit Model is designed to predict changes in transit ridership due to changes in transit fares or level of service.

Use

MODE CHOICE estimates changes in mode split. By changing the times and costs of the different modes to reflect the changes which could occur or would be desirable during reconstruction and comparing those splits to the present splits, the user could determine what changes would be the most beneficial to institute during the reconstruction process,

The RTD Pivot Point Logit Model can be used to predict the changes in mode split resulting from changes in transit and traffic operations during reconstruction or improvements in service that result in time or cost changes to the public if they take transit.

Limitations

The limitation with both the RTD Pivot Point Logit Model and MODE CHOICE is that the utility function coefficients (the weights given to the different variables in the model) may not correspond to the particular area being studied, in which case they would have to be adjusted. The programs also require the use of a spreadsheet program such as Lotus i-2-3 or SuperCalc. These programs only revise a base-case estimate of mode split; they will not develop the initial estimate.

Data Requirements

Data requirements for MODE CHOICE include:

- o Socio-economic data: subgroup per population, income, cars per household, average household size, drivers per household, proportion of working subgroup which are principal wage earners in their household
- o Level-of-service attributes for each mode: one-way distance, parking cost, auto cost per mile, average Carpool size, one-way transit fare, one-way in-vehicle and out-of-vehicle time

These data should be fairly easy to acquire and, for best application, should be collected for an individual "travel subgroup." A travel subgroup is usually defined geographically (workers living in area A and working in the CBD, for example).

The data requirements for the RTD version of the pivot point logit model fall into two categories, existing mode shares (for all available modes for each trip purpose) and level-of-service changes (including the operations and/or policy changes to be analyzed). The two formulations of the spreadsheet in the RTD Pivot Point Logit Model are the Denver Unified Travel Patterns Model and the Cambridge Systematics Model (which uses approximately the same model coefficients, in-vehicle and out-of-vehicle travel time, out-of-pocket travel cost, and shared-ride incentive as does the MODE CHOICE model). The specific data requirements for each formulation are as follows:

- o Base mode shares for each trip purpose (Denver & Cambridge)
- o Base transit ridership for each trip purpose (Denver)
- o Changes in in-vehicle travel time and out-of-vehicle travel time in minutes (Denver & Cambridge)
- o Changes in travel cost (Denver)

- Average Carpool size (Cambridge)
- One-way travel distance (Cambridge)
- Annual income (Cambridge)
- Changes in out-of-pocket travel cost (Cambridge)
- Presence or absence of shared-ride incentive (Cambridge)

Typical Output

Both MODE CHOICE and the RTD Model produce estimates of the number of commuters who will take transit, share a ride or drive alone given a set of expected travel times and costs.

Advantages and Disadvantages

Both MODE CHOICE and the RTD Model are easy to use. The data collection is not time intensive and as long as one knows how to use a spreadsheet (Lotus l-2-3, SuperCalc) the results are easy to acquire.

Success at Forecasting Travel During Actual Reconstruction

Neither MODE CHOICE nor the RTD Model have been used for planning a reconstruction project.

Appropriateness for Reconstruction Project Travel Impact Evaluation

Both MODE CHOICE and the RTD Pivot Point Logit Model can be used to estimate the impact of policy changes designed to encourage increased transit or shared-ride patronage as part of a reconstruction project.

HIGHWAY CAPACITY ANALYSIS PROCEDURES

Highway capacity analysis is an essential component of the evaluation of the travel impacts of highway reconstruction projects. Capacity estimates are required both for the highway being reconstructed and for alternative routes and modes in the corridor. Capacity estimates are required for the before-reconstruction condition (to identify alternative traffic management plans) and for during-reconstruction conditions (to evaluate the travel impacts of each alternative). Predictions of the travel impacts are probably more sensitive to capacity than to any other variable. The 1985 Hiahway Capacity Manual (HCM) (7) is the widely accepted resource for capacity analysis procedures. The Highway Capacity Software (HCS), which was developed under FHWA sponsorship, is a "faithful replication of the procedures found in the 1985 HCM" (14) The Microcomputers in Transportation Software and Source Book (2) identifies 16 other microcomputer-based capacity analysis procedures, most of which are also based upon the 1985 HCM. This discussion focuses on the HCM and HCS procedures, but for the most part other packages could also be used to perform the same analyses as a matter of individual or organizational preference.

Application and Purpose

The 1985 HCM is a compilation of the best techniques for estimating highway capacity that were available at the time of its publication. Highway facilities are divided into two categories: uninterrupted and interrupted flow. Uninterrupted flow facilities include basic freeway segments, ramps, weaving sections, multilane highways, and two-lane highways. Interrupted flow facilities include signalized and unsignalized intersections, and arterials. Capacity analysis procedures are also provided for bus and rail transit.

The HCM provides procedures for three levels of analysis: operational, design, and planning. The levels differ in their data requirements and outputs. The level of analysis that should be used depends on the types of results that are needed.

The operational analysis procedure is the most detailed level of analysis and requires the most detailed input information. The objective in operational analysis is to estimate the level of service, and associated operational MOEs, for known or projected traffic volumes and known or projected roadway characteristics. The procedure can be worked backward to produce service volumes based on desired levels of service. This type of information is likely to be needed in evaluating the travel impacts of a reconstruction project.

The design procedure uses the same types of input information as operational analysis. However, the procedures have different objectives. The design procedures for basic freeway segments and multilane highways estimate the number of lanes required . to provide a specified level of service. On the other hand, the design procedure for signalized intersections is used to evaluate signal timings.

The planning procedure "is intended for rough estimates at the earliest stages of planning when the amount, detail, and accuracy of information are limited" (7) The planning procedure for basic freeway segments and multilane highways has the same objective as the design procedure: to estimate the number of lanes required to provide a specified level of service. The procedure typically uses forecasts of AADT and assumed roadway and traffic characteristics. The planning procedure for signalized intersections assesses whether a signalized intersection has adequate capacity to accommodate forecasted traffic volumes; the only roadway information that is required is the number and type of approach lanes.

The operational analysis procedure provides the types of output that are most likely to be needed in planning reconstruction projects. The HCS operational analysis procedures for basic freeway segments and multilane highways are so quick and easy to use that the planning level procedures offer little advantage in terms of required effort. In the case of signalized intersections and arterials, planning procedures are much less data-intensive and rigorous than operational analyses. The results are, as expected, less reliable. Planning procedures would be applicable in identifying significant bottlenecks early in the planning and alternatives evaluation stages.

Use

Capacity analysis is required throughout the process of evaluating the travel impacts resulting from reconstruction projects. The inventory of the affected corridor includes the estimation of the capacities of the highway being reconstructed as well as the alternative routes in the corridor. The changes in capacity on the highway being reconstructed and the availability of unused capacity on alternative routes are major determinants of the magnitude of travel impacts. Even in the early stages of planning, it is desirable that capacity estimates be as accurate as possible. However, detailed information on the geometry of the reconstruction zone may not be available and it may be necessary to make assumptions about roadway characteristics, such as lane and shoulder widths, for various traffic handling options in order to estimate capacities through the reconstruction zone.

Information on the availability of unused capacity on alternative routes is also vital in the early stages of planning when traffic-handling options are being considered. The amount of unused capacity elsewhere in the corridor influences the magnitude of capacity reductions that are feasible on the highway being reconstructed. The number of alternative routes may be large, and it may be difficult to do detailed capacity analyses for all routes. Knowledge of the local system should enable the analyst to identify the most viable alternative routes and the most critical bottlenecks. However, more objective, quantitative assessments are desirable. Alternative freeways and multilane highways could quickly and easily be analyzed using the HCS operational analysis procedures. The use of operational analysis procedures for key signalized intersections on alternative arterial routes would be more time consuming. If time and manpower are limited, the planning level procedures for signalized intersections might be used to identify critical bottlenecks.

Limitations

The most significant limitation of the HCM and HCS with respect to their use in planning a reconstruction project is the limited amount of information available on the effect of work zone activities on capacity. Chapter 6 of the HCM summarizes the data that are available from studies in Texas by Dudek and Richards (15) and in California by Kermode and Myyra (16) Most of the data are for short-term maintenance sites. Capacity data for long-term construction activities with portable concrete barriers are reported for only 10 sites. The 1985 HCM presents the capacity estimation procedures for short- term work zones that were developed by Dudek and Richards; however, those procedures are not included in the HCS.

The most reasonable approach for estimating the capacity of long-term freeway reconstruction zones would be to use the standard adjustment factors presented in the 1985 HCM to account for the effect of reduced design speed, lane width, and lateral clearance. As the HCM suggests, sound judgment must be used in selecting appropriate adjustment factors for restricted lateral clearances to concrete barriers, since some evidence suggests that these barriers have minimal impact on capacity. There may also be an additional reduction in capacity due to the presence of work activity adjacent to travel lanes; however, the magnitudes of such reductions have not been quantified.

The HCM emphasizes that the procedures are calibrated and based upon assumptions for average conditions in the United States and, therefore, may not precisely represent actual conditions in specific locales. Thepotential for discrepancies between estimated and actual conditions is greatest in the planning procedures which are based upon the most assumptions. The HCM urges analysts to calibrate the procedures for local conditions whenever possible.

Data Requirements

The data requirements for capacity analysis include information on roadway, traffic, and control conditions. The roadway conditions that affect capacity include the type of facility and its development environment (the frequency of unsignalized intersections and driveway entrances to the facility), lane widths, lateral clearances, design speed, and alignment. Important traffic conditions include vehicle types as well as both lane and directional distribution. Control conditions include the type of control (signal, STOP, or YIELD) and, for signals, the timing and phasing. The data requirements depend on the type of facility being analyzed and the level of analysis being performed.

Uninterrupted flow facilities, by definition, have no external controls that force traffic to stop. Therefore, the data requirements are limited to descriptions of roadway and traffic conditions. The operational analysis procedure requires data on the following roadway characteristics: design speed, lane widths, lateral clearances, and vertical alignment (which may be specified as a general terrain type or a length and percentage of grade). The traffic condition data required to perform an operational analysis include directional hourly volumes; percentages of trucks, buses, and recreational vehicles; peak hour factors; and a driver population classification (weekday commuter or weekend). The planning procedure requires only a general terrain classification, a forecasted AADT, and the approximate percentage of trucks.

The data requirements for the operational analysis of signalized intersections are more extensive. Data required for each approach include geometric conditions (area type, number of lanes, lane widths, percentage of grade, existence of exclusive and shared lanes, length of turning lanes, parking conditions); traffic conditions (volumes by movement, peak hour factor, percentage of heavy vehicles, conflicting pedestrian flow rates, number of local buses stopping at the intersection, parking maneuvers per hour, arrival type); and signalization conditions (cycle length, green times, actuated or pretimed operation, existence of pedestrian push button, minimum pedestrian green, phase sequence).

The planning level procedure for signalized intersections requires data only on demand volumes and basic intersection geometry. Hourly demand volumes by movement are required for each approach. The required geometric data include the number and utilization of lanes on each approach.

Typical Output

The outputs depend upon the level of analysis and type of facility. For uninterrupted flow facilities, the operational analysis level provides estimates either of the capacity of the facility or of the level of service (and corresponding average speed and density) for a specified traffic volume; both the design and planning procedures provide as output estimates of the number of lanes required to accommodate a specified demand volume at a desired level of service.

For signalized intersections, the operational analysis level provides estimates of the volume/capacity ratio, levels of service, and corresponding delays for each lane group and for the intersection as a whole. The design procedure is available for signal timing. The planning level procedure provides an indication of whether or not the intersection geometry is likely to have sufficient capacity to accommodate specified demand volumes.

Advantages and Disadvantages

The HCS is very easy to use. The software has separate modules for each facility type. The software is menu driven with a main menu that provides access to each module. The software prompts the user for all input data. Analysts familiar with the 1985 HCM can use the software without referring to the software's User's Manual

The time and effort required to use the HCS, exclusive of the data collection effort, is minimal. The effort to satisfy the data requirements depends upon the level of analysis to be performed. For planning level analysis, the data requirements are minimal and should be satisfied with information already in hand. Even for the more detailed operational analysis level, the data requirements involve information that is either readily available in the office or that can be collected using standard procedures at the site. Of course, the data collection effort, when multiplied by a large number of sites to be analyzed, can be time consuming.

Capacity analysis procedures, either the HCS or the numerous alternatives identified in the Microcomputers in Transportation Software and Source Book (2) provide results that are vital to the success of the planning process. The accuracy of estimates of capacities through reconstruction zones is uncertain because of the limited amount of information available on work zone capacity, especially for long-term activities.

Success at Forecasting Travel During Actual Reconstruction

There is insufficient evidence to judge the success of 1985 HCM and HCS procedures in estimating capacities through reconstruction zones. The use of standard adjustment factors for reduced lane widths and restricted lateral clearances appear to provide reasonable results, but the additional reduction in capacity due to the presence of work activity adjacent to the travel lanes has not been quantified and is left to the judgment of the analyst.

Several researchers have evaluated whether the relationship between speed and volume/capacity ratio for normal operating conditions is applicable for work zone conditions. The results have been mixed. Butler (17) concluded that the speed-volume relationship for work zones did correspond to the typical relationship for normal freeway sections in the 1965 HCM. Abrams and Wang (3) also used the typical relationships in the 1965 HCM as the basis of their estimation of speeds through work zones. However, Rouphail and Tiwari (18) concluded that the speed-volume relationships for a sample of four lane closures in Illinois were different from the relationships in the 1965 HCM. They reported an average difference of 3 mph between the speeds reported in the 1965 HCM and the speeds observed through work zones at similar volumes, percentages of trucks, lane widths, and lateral clearances. Additional research will be necessary to validate capacity estimation procedures and speed-volume relationships for long-term reconstruction zones.

Appropriateness for Reconstruction Project Travel Impact Evaluation

The 1985 HCM presents the best available procedures for capacity analysis. Use of the HCS, or other similar software packages, is appropriate at various stages of the planning process. When time and manpower permit, the more detailed operational analysis procedures, particularly for freeways or multilane highways, should be used to provide the most accurate results possible. The use of the HCM planning level procedures for signalized intersections, which require less detailed data, is also appropriate for identifying bottlenecks on alternative routes in the early stages of planning.

TRAFFIC SIMULATION MODELS

Traffic simulation models are among the most detailed methods available for the analysis and prediction of operating conditions on streets and highways (19) Generally speaking, simulation models are important tools for the engineer to evaluate the time-varying nature of traffic flows and operating conditions (20) The models are also important tools for evaluating complex roadway situations where the effects of several geometric and traffic factors are present and their impacts upon the overall flows and operating conditions are interrelated. Simulation models generally provide several types of operational measures of effectiveness (MOEs) such as stops, delays, speeds, vehicle queuing characteristics, cycle failures, fuel consumption, and vehicle emissions.

There exists a wide range in the capabilities and characteristics of simulation models. The models vary in the complexity of their analysis of traffic flows, from simple input-output analysis of traffic upstream from a capacity restriction (21-23) to complicated models of urban arterial network operations based on microscopic traffic flow and car-following relationships (24). Simulation models also vary in the type of roadway geometrics they were designed to analyze. For the purposes of this review, traffic simulation models are divided into four categories:

- Freeway lane closure models--QUEWZ, DELAY, FREWAY
- Freeway corridor simulation models--FREQ, TRAFLO, INTRAS
- Urban arterial network simulation models--TRAFLO, NETSIM
- Freeway corridor assignment models--PASSER-IV, TRAFLO

Recent reviews of most of the existing models in each of these categories have been performed by others (25-27). The objective of this analysis is to compare the well-known or state-of-the-art models in each category with respect to their application and purpose, use, limitations, data requirements, output, advantages and disadvantages in the reconstruction planning process.

Freeway Lane Closure Models

Three existing models can be used to evaluate the travel impacts of capacity reductions: QUEWZ, DELAY, and FREWAY. All three models use input-output analysis to estimate the queuing characteristics.

QUEWZ, which stands for Queue and User Cost Evaluation of Work Zones, was developed for the Texas State Department of Highways and Public Transportation (TSDHPT) by the Texas Transportation Institute. The original, mainframe-computer version of the model was developed in 1982 (21, 28). Several enhancements to the mainframe version have already been reported (29). Additional enhancements are being made as part of an ongoing research effort, and this third version is referred to as QUEWZ3. A microcomputer version QUEWZ-85 has also been developed (30)

DELAY is a LOTUS l-2-3 spreadsheet developed under FHWA sponsorship that estimates queuing characteristics--total delay, time to normal flow, maximum number of vehicles in queue, and maximum length of queue in miles--resulting from freeway bottlenecks due to lane closures during either maintenance activities or freeway incidents (31). FREWAY is a microcomputer program developed by Rouphail, Spencer, and Rivers (22. 32); it performs routine capacity analyses for basic freeway segments under normal operating conditions (based upon 1965 HCM procedures) and delay calculations for work zone lane closures (based upon input-output analysis).

The capabilities of DELAY and FREWAY are a subset of the capabilities of QUEWZ3. QUEWZ3 has the broadest range of capabilities and will be the focus of this review.

Application and Purpose

QUEWZ3 was developed as a tool for evaluating highway work zone lane closures. It was developed to computerize commonly used manual techniques for estimating the queue lengths and additional road user costs resulting from lane closures. It was intended as a tool for simplifying the evaluation of the travel impacts of alternative lane closure configurations for short-term work zone operations. QUEWZ3 was designed to analyze freeway facilities but can also be applied to multilane highways. QUEWZ3 can analyze work zones with any number of lanes closed in one or both directions of the highway facility.

QUEWZ3 models traffic flows through a highway segment at a macroscopic level. A speed-volume relationship is used to estimate average speeds. Input-output analysis, as described in Chapter 6 of the 1985 HCM, is used to estimate queuing characteristics. QUEWZ3 computes speed profiles through the highway segment with and without the work zone lane closure and then uses those profiles to estimate the additional road user costs per hour due to the work zone.

The scope of the model's analysis is limited to the highway on which the lane closure occurs. Its primary application is the estimation of the additional road user costs associated with the difference in traffic conditions on the highway with and without the lane closure. No attempt has been made to estimate corridor-wide impacts, that is, to consider the impacts that diversion away from a work zone has on traffic conditions on alternative routes in the corridor.

The original mainframe version of QUEWZ and the microcomputer version QUEWZ-85 assumed that no traffic diverted away from the highway in response to work-zone-related delays. When historical volume counts were input as demand volumes, QUEWZ tended to overestimate queue lengths because it did not account for the fact that the actual volumes through the work zone were less than historical volumes by the amount of diverting traffic. One of the enhancements incorporated into QUEWZ3 has been the addition of a simple diversion algorithm. The algorithm assumes that enough traffic will divert so that delays on the freeway never exceed a maximum acceptable level. QUEWZ3 computes diversion as a function of delays on the freeway itself. It is assumed that unused capacity is available on alternative routes, but no attempt is made to verify that assumption or to assign traffic to specific routes. Currently, a research project is being conducted at the Texas Transportation Institute under the sponsorship of the Texas State Department of Highways and Transportation which has as one objective the refinement and validation of a diversion algorithm for QUEWZ3.

Use

QUEWZ3 might be used in several ways in the reconstruction project travel impact evaluation process. The primary application of QUEWZ3 would be to estimate the travel impacts of alternative lane closure configurations on the highway being reconstructed. Impacts are reported in terms of average speeds, queue lengths, and additional road user costs. The demand volumes that are input to QUEWZ3 may either be (1) historical volume counts, in which case QUEWZ3 could estimate diversion, or (2) estimates of the actual volumes through the work zone based upon some form of traffic assignment procedure, in which case one could set an input parameter to override the diversion algorithm in QUEWZ3.

QUEWZ3 could also be used to estimate the amount of traffic that would have to divert away from a specified lane closure configuration so as not to exceed particular delay levels through the work zone.

Alternatively, QUEWZ3 could be used for scheduling purposes to identify the times of day when lanes could be closed without causing excessive delays to motorists.

Limitations

QUEWZ3 was designed to evaluate work zone lane closures on freeways or multilane highways. Work zone configurations that maintain the same number of lanes by reducing lane and shoulder widths are not accommodated. QUEWZ3 treats the work zone as a simple bottleneck in which all traffic enters at the upstream end and exits at the downstream end. QUEWZ3 has no provisions for analyzing the effects of complex configurations involving ramps, weaving areas, or separate HOV lanes within the work zone, unless it is reasonable to approximate the configuration as a simple bottleneck.

QUEWZ3 analyzes only the travel impacts on the highway being reconstructed. It does not consider alternative routes in the corridor and cannot be used to evaluate impacts on those routes. The measures of effectiveness reported by QUEWZ3 are volumes, capacities, average speeds, queue lengths, and road user costs. QUEWZ3 computes but does not report travel times and delays.

QUEWZ3 can analyze only one twenty-four-hour period at a time.

Data Requirements

The data requirements depend upon the output option that is desired. Some or all of the following information may have to be supplied by the model user: (1) the configuration of the work zone, (2) the schedule of work activity, (3) the traffic volumes approaching the highway segment, and (4) alternative values to the defaults provided for various model constants.

Configuration of the Work Zone. The configuration of the work zone is described by the lane closure strategy (closure in one or both directions), the length of the work zone, the total number of lanes in each direction, and the number of lanes open through the work zone in each direction.

Schedule of Work Activity. The schedule of work activity is specified by the beginning and ending hours of restricted capacity (i.e., the lane closure) and the beginning and ending hours of work activity. The hours of restricted capacity are the time period during which the lane closure is in place. The hours of work activity, which may or may not be the same as the hours of restricted capacity, are the time period during which work activity is actually in progress.

Traffic Volumes. QUEWZ3 requires directional hourly traffic volumes. Daily, hourly, and directional distribution factors have been developed for typical traffic patterns in Texas. Therefore, the volume data requirements can be satisfied by providing either (1) directional hourly traffic volumes explicitly or (2) the AADT of the roadway as well as the day and month when the lane closure will be in effect. The user may choose to (1) estimate diversion separately and supply estimates of the actual volumes that will pass through the work zone or (2) supply approach volumes to the work zone and ask QUEWZ3 to estimate the portion of those volumes that will divert.

Alternatives to Model Default Values. The user may supply alternative values to the default values provided for the following model constants: (1) cost update factor, (2) percentage of trucks, (3) parameters for the speed-volume relationship, (4) capacity estimate risk factor, and (5) definition of excessive delay. The cost update factor is the ratio of the Consumer Price Index for the analysis period and the Consumer Price Index for December 1981 and is used to update costs which by default are expressed in December 1981 dollars. The parameters for the speed-volume relationship define the ranges of speed and volume over which a linear and a quadratic relationship should be used. The capacity estimate risk factor is used to select a work zone capacity from cumulative distributions of observed capacities; it is the percentage of work zones at which observed capacities equaled or exceeded a particular value. A definition of excessive delay is used in the diversion algorithm and in the lane closure schedule option. Excessive delay may be defined in terms of either minutes of delay or length of queue in miles. The default definition is 20 min of delay.

Typical Output

QUEWZ3 has two output options: the road user cost option and the lane closure schedule option.

The road user cost output option analyzes a user-specified work zone configuration and schedule of work activity. The output consists of estimates of traffic volumes (both remaining on the highway and diverting away from the work zone), capacities (with and without the work zone), average speeds (with and without the work zone), queue lengths (with the work zone), and additional road user costs for each hour the lane closure is in place.

The lane closure schedule option analyzes all possible lane closure configurations on a highway segment with a specified number of lanes. The output identifies, for each possible number of lanes closed, (1) the hours of the day when that number of lanes could be closed without causing excessive queuing or delays and (2) the estimated length of queue during each hour of the day. The model user defines the length of queue or minutes of delay that are excessive.

Advantaaes and Disadvantaaes

A major advantage of QUEWZ3 in the context of planning reconstruction projects is that it was designed specifically to evaluate alternative work zone configurations. QUEWZ3 is relatively easy to use. The data requirements are fairly easily satisfied. QUEWZ3 provides hourly estimates of traffic conditions on the highway both with and without the work zone in place and is one of the few traffic simulation models that provide output on road user costs.

QUEWZ3 is limited in the types of highway facilities and in the types of work zone configurations it can analyze. QUEWZ3 was designed for basic freeway segments or multilane highways. It does not have the capability to consider more complex situations such a ramps or weaving areas. QUEWZ3 was designed to analyze only work zone configurations in which one or more lanes are closed. The coding does not permit the analysis of work zone configurations in which there are capacity reductions due to reduced lane and/or shoulder widths but no lane closures. QUEWZ3 analyzes only the highway on which the work activity occurs.

For QUEWZ3 as for any model, the quality of the output is dependent upon the quality of the input. QUEWZ3 is particularly sensitive to the approach volume and work zone capacity estimates that are used. The user may either supply volumes that already account for diversion or supply normal approach volumes and allow QUEWZ3 to estimate diversion. The accuracy of the existing diversion algorithm has not yet been validated. The user also has the option of supplying estimates of work zone capacity or allowing QUEWZ3 to estimate the capacity. QUEWZ3 incorporates the work zone capacity estimation procedure that was developed by Dudek and Richards (15) and included in the

1985 HCM. The procedure is based upon a limited number of observed capacities at short-term work zone lane closures in Texas. QUEWZ3 does not allow user-supplied work zone capacities to be greater than 90 percent of the normal capacity.

Success at Forecasting Travel During Actual Reconstruction

QUEWZ has been used in several Texas cities, including Fort Worth, San Antonio, and Houston. In Fort Worth, for example, maintenance engineers with the TSDHPT used QUEWZ to estimate queue lengths in order to determine the distance upstream of a lane closure at which supplemental advance warning signs should be placed. In San Antonio, a traffic engineer used the original version of QUEWZ to estimate the effect of a proposed lane closure on a downtown freeway segment. The model predicted unreasonably long queues (because no account was made of diversion). Although queue lengths of the magnitude predicted were not likely to occur, the results suggested that serious problems could arise and prompted a reassessment of the proposed lane closure. The diversion algorithm in QUEWZ3 is being validated as part of an ongoing research effort.

Denney and Levine (33) have provided a more formal discussion of the use of the original version of QUEWZ for evaluating active traffic management strategies during work activity on the Southwest Freeway in Houston; they concluded that "the QUEWZ computer model has been shown to provide reasonable evaluations of the effectiveness of these strategies."

Appropriateness for Reconstruction Project Travel Impact Evaluation

QUEWZ3 would be an appropriate model for evaluating the impacts of alternative work zone lane closure configurations and in estimating average speeds, queue lengths, and additional road user costs for the alternative configurations. DELAY or FREWAY could be used to estimate delays and queuing characteristics for freeway capacity reductions.

Freeway Corridor Simulation Models

Application and Purpose

Complex simulation models for freeway and freeway corridor analysis have become quite important for evaluating alternative traffic management and traffic control strategies over the past several years. Freeway corridor simulation models have been designed to aid in the analysis and prediction of travel conditions over time, given specific geometric characteristics and traffic demand for the freeway section of interest. Typically, this is accomplished by separating the analysis into incremental units, or “slices” of time over which conditions (demands, capacities, etc.) are approximately constant. The time slices are then analyzed sequentially, which allows the impacts from previous slices to affect conditions during the slice currently being evaluated.

Over the past several years, freeway corridor models have undergone fairly intense review and appraisal (25, 26) At the present time, three models exist that enjoy widespread use or represent state-of-the-art implementable technology in this category: FREQ, TRAFLO, and INTRAS.

The FREQ series of models have evolved over the years at the University of California-Berkeley. The original model was developed to aid engineers in the analysis of proposed improvements along 140 miles of freeway in California. The model has been expanded and improved to include the simulation of freeway entry control strategies (34) and high-occupancy vehicle lanes (35). An important component of FREQ is its ramp metering optimization routine. The model is deterministic and macroscopic, and has received widespread validation and use in analyzing proposed geometric improvements and various traffic control strategies across the country (27, 36, 37).

TRAFLO (36) is the deterministic, macroscopic portion of the integrated traffic simulation package TRAF, which is being developed under the supervision of FHWA (20). TRAFLO consists of the NETFLO models of urban arterials together with a freeway component FREFLO and a traffic assignment package TRAFFIC. The integrated structure of TRAFLO provides for a simultaneous, coordinated analysis of proposed changes or control strategies within a corridor upon operating conditions on both the freeway and the surface street system. However, TRAFLOs modular design also allows for the use of either the freeway or the arterial components (FREFLO and NETFLO) alone if a more limited analysis is desired.

In the future, the TRAF simulation package will also include a microscopic model of freeway traffic. The model developed for this purpose, INTRAS (39-42), is being reprogrammed and modularized and will be renamed FRESIM (43) INTRAS, developed by KLD and Associates, is a stochastic freeway simulation model based on car-following, lane-changing, and crash avoidance algorithms. The model allows for a detailed analysis of unusual or extremely complex traffic operations throughout a freeway section.

Use

Freeway corridor simulation models provide the engineer and planner a means of evaluating the impact of geometric changes due to reconstruction (such as shoulder removal, reduced lane widths, detours) upon travel time, operating speeds, and queuing patterns on the freeway and alternative parallel route(s). In addition, simulation can be used to estimate the effect of candidate traffic management and impact mitigation strategies for the freeway during reconstruction. Examples of such strategies include off-peak lane closures, ramp closures, ramp metering, and priority (HOV) lanes. Table B-l identifies some of the uses for freeway corridor simulation for reconstruction project travel impact evaluation, and the ability of each model to address them.

FREQ can be used to evaluate and analyze one directional freeway segment at a time. Geometric conditions that are constant during a simulation period (such as permanent lane closures, removal of ramps, and detours) can be simulated. Also, ramp metering can be modeled and ramp metering rates optimized if desired. Diversion of entrance ramp traffic to a single alternative parallel route can also be estimated and evaluated by FREQ.

As Table B-l indicates, TRAFLO is a powerful tool, capable of analyzing a wide variety of situations. TRAFLO has several capabilities in addition to those of FREQ including the ability to handle several freeway segments at a time and to account for the entire arterial street system within the freeway corridor (at varying levels of detail, if desired). This latter capability allows the user to more easily estimate the impacts of improvements to alternative routes on overall freeway corridor traffic operations. Another important aspect of TRAFLO is its traffic assignment capabilities. The TRAFFIC module of TRAFLO is an assignment model based on either user or system equilibrium, depending on the option selected. This model can be used to estimate the changes in corridor-wide travel patterns resulting from capacity reductions on the highway being reconstructed as well as to investigate the effect of increases in capacity on alternative routes (through various TSM strategies).

TABLE B-l. SOME USES OF FREEWAY CORRIDOR SIMULATION MODELS

Evaluate **the Impacts of:**	**FREQ**	**TRAFLO**	**INTRAS**
Permanent Lane Closures, Ramp Closures, or Lane Drops	**Yes**	**Yes**	**Yes**
Reduced Lane/Shoulder Widths	Limited	Limited	Yes
Minor Changes in Geometrics	Limited	Limited	Yes
Ramp Metering	Yes	Yes	Yes
HOV (Priority) Lanes	Yes	Yes	No
Temporary Lane Closures, Ramp Closures, or Incidents	Yes	Yes	Yes
Surveillance and Control	Yes	Yes	Yes
Diversion (Traffic Reassignment)	Limited	Yes	Limited
Consideration of Changes on Alternative Routes	Limited	Yes	Limited

INTRAS, because it is a microscopic model of freeway corridor traffic, provides the most detailed level of analysis and greatest capabilities of the three models listed. INTRAS allows the user to consider the impacts of minor changes in ramp geometrics, vehicle performance, and driver behavior characteristics. However, INTRAS at the present time cannot explicitly consider HOV lane operations.

<u>Limitations</u>

There are major limitations with using any of the simulation models in assessing the impacts of reconstruction. The most severe limitation is that capacity values, in all models except INTRAS, and driver behavioral response characteristics (which are known to have significant bearing upon the simulation results) must be estimated by the user during the analysis of reconstruction geometry and impact mitigation strategies. Estimates of demand and capacity before reconstruction are usually known or can be obtained through calibration of the model to observed conditions. However, predicting driver behavior, travel demand, and roadway capacity during reconstruction is much more difficult.

Only limited information is available on reconstruction zone capacity (7). Changes of travel demand in response to highway reconstruction have not been studied in great detail to date, and are difficult to predict with confidence. FREQ8PE (44) has (as part of its ramp metering optimization) algorithms for estimating temporal, spatial (to downstream entrance ramps), and modal diversion of entrance ramp vehicles that experience delay on the ramp. However, the model does not allow drivers to exit from the freeway and divert to alternative routes in order to avoid congestion on the freeway. Other specific limitations of FREQ include (1) the analysis of only one directional freeway segment at a time, and (2) the ability to consider only one alternative route (for entrance ramp diversion) in an extremely simplified manner.

The traffic assignment module in TRAFLO can be used to estimate changes in travel patterns (based on either user or system equilibrium traffic assignment) due to changes in roadway configuration that significantly and consistently influence roadway capacity (e.g., permanent lane closures or opening a new alternative route), but because the assignment procedure is based upon a simplified relationship between travel time and the volume/capacity ratio, its use to estimate dynamic changes in travel volumes due to time-dependent strategies such as temporary lane and ramp closures, time-dependent signal timing changes, or peak-period turn restrictions on alternative routes may not be appropriate.

A limitation of INTRAS at the present time is its inability to explicitly consider and evaluate HOV lane operations. In addition, the capability of INTRAS to estimate and model diversion or traffic reassignment is limited.

Data Requirements

The data requirements for the freeway corridor simulation models are fairly uniform. Each model uses a general link-node approach to represent the corridor, and so geometric data describing the links and nodes (such as link lengths, number of lanes, capacities (for FREQ and TRAFLO), etc.) are needed. TRAFLO allows these geometric data to be changed within the simulation run (to simulate effect of temporary reductions in capacity) while FREQ requires the geometrics to remain constant during the simulation. INTRAS explicitly models incident conditions by specifying the closing or reduced capacity of longitudinal portions of one or more lanes.

A significant portion of the input for all corridor models is the specification of the amount of traffic demand using the corridor throughout the simulation period. FREQ requires this information in the form of a freeway ramp origin-destination matrix for each time period being simulated. A method is available, however, to generate this matrix synthetically from ramp volumes, and research has indicated that the matrix obtained provides realistic estimates of actual operating conditions (45.46).

Travel demands for TRAFLO can be input as link volumes and turning percentages on the links throughout the network, or a zonal origin-destination trip table can be used (via the TRAFFIC assignment model) to obtain these volumes and percentages. Use of the assignment routine will require substantially more data, resulting in more time and effort for the input process. INTRAS uses actual freeway link volumes and turning percentages, input by the user, to develop a freeway link O-D matrix. However, the user can override any of the cells in the matrix through separate inputs.

Typical Output

FREQ, TRAFLO, and INTRAS all provide detailed information about operating conditions link-by-link and throughout the corridor at several points in time and also for the entire simulation period. Specific items presented in the output reports include:

- Total Travel (Vehicle-Trips and/or Vehicle-Miles)
- Total and Average Travel Times and Delays

- o Average Speeds, Densities, V/C Ratios
- o Fuel Consumption and Vehicle Emissions

FREQ also presents basic information concerning conditions on one alternative route, entrance ramps, and optimized ramp metering settings. FREQ can also provide queue profiles as an aid in evaluating the temporal and spatial development of congestion. Outputs for TRAFLO, in addition to the above information for the freeway portion of the network, include similar information for the arterials. The microscopic analysis provided by INTRAS can also output speed profiles (contours), headways, and vehicle trajectories.

Advantages and Disadvantages

Table B-2 summarizes the primary advantages and disadvantages of FREQ, TRAFLO, and INTRAS. FREQ appears to be easier to use than TRAFLO, and has abilities to explicitly optimize ramp metering strategies. However, the treatment of alternative routes within the corridor is limited, and no mechanism exists for allowing drivers on the freeway to divert to alternative routes. Also, unlike TRAFLO and INTRAS, FREQ does not explicitly model freeway-to-freeway interchanges. Instead, the segment must be split into linear sections, and the interaction modeled implicitly by the user.

The major advantage of the TRAFLO model is its ability to deal with an entire freeway corridor and to customize the network by representing various parts with TRAFLO LEVEL I or II. As such, the effects of TSM improvements on the alternative routes (such as signal timing changes or channelization) or of freeway-specific mitigation strategies (such as ramp closures or off-peak lane closures) upon operations throughout the corridor can be examined. Another advantage of TRAFLO is the TRAFFIC assignment module which can predict the changes in travel patterns resulting from changes in roadway capacity. The primary disadvantages to TRAFLO are its extensive data requirements.

INTRAS can simulate complex situations and can be adjusted and calibrated through numerous roadway, driver, and vehicle parameters. Consequently, the program can be used to examine complicated weaving or ramp sections. Unfortunately, the early versions of the model were not very user friendly (43) although the new reprogrammed FRESIM version is expected to be easier to use. INTRAS also requires large amounts of data and long processing times.

TABLE B-2. ADVANTAGES AND DISADVANTAGES OF FREEWAY CORRIDOR SIMULATION MODELS

	FREQ	TRAFLO	INTRAS
ADVANTAGES	Easiest of the Three Models to Use Optimization of Ramp Metering Considerable Testing, Validation, and Use Nationwide	Explicit Treatment of Freeway and Surface Street System (Geometrics, Intersection Control, Signal Timings) Can Evaluate Temporary Changes in Roadway Characteristics Can Use Zonal O-D Data to Estimate Changes in Travel Patterns (TRAFFIC)	Explicit Treatment of Freeway and Surface Street System(Geometrics, Intersection Control, Signal Timings) Can Evaluate Temporary Changes in Roadway Characteristics Can Evaluate Complex Weaving Sections Can Evaluate Minor Geometric Changes and Vehicle/Driver Characteristics
DISADVANTAGES	Only 1 Directional Freeway Segment Can Be Evaluated Only 1 Simplified Parallel Alternative Route Can Be Modelled	Extensive Input Data Required	Extensive Input Data Required Long CPU Times Required

Success at Forecasting Travel During Actual Reconstruction

Previous use of freeway corridor simulation models for evaluating the travel impacts of reconstruction projects has been quite limited to date. Little time and effort has been expended in the past on the detailed simulation analysis of the effect of reconstruction options and potential mitigation strategies upon traffic conditions on either the highway being reconstructed or on alternative routes in the corridor. A few occasions where simulation has been used to evaluate the impacts of highway reconstruction are discussed below.

US 59 (Southwest Freeway Houston. TX. FREQ was used to estimate the additional road user costs during the planned reconstruction of the Southwest Freeway in Houston (47) The freeway is congested and suffers from operational breakdowns and stop-and-go conditions during the peak periods. The traffic control plan for this project involves several phases and some detours of the freeway mainlane traffic, but only minor changes in lane widths. Even with small (3 percent) reductions in link capacities below those of normal conditions, large queues and stop-and-go conditions were predicted to occur all day long during reconstruction. Since FREQ does not explicitly consider diversion or changes in travel patterns, it is difficult to say how meaningful these predicted results may be.

I-405. Seattle, WA. TRAFLO is being used to a limited degree on a reconstruction project currently in the planning phase on I-405 in Seattle. Data collection before, during, and after reconstruction is planned, and it is hoped that it can be used to determine how useful the TRAFLO model may be for reconstruction project travel impact evaluation.

I-5. Orange County, CA. As part of a research study for the California Department of Transportation, a prototype data-managing environment to aid engineers in the use of simulation to analyze traffic impacts due to major reconstruction projects was developed by researchers at the Institute of Transportation Studies (ITS), University of California-Irvine. The environment, labeled CARHOP (for Computer Assisted Reconstruction strategies for Highway Operations and Planning), was intended as a tool to allow the user to easily evaluate the impact of alternative reconstruction scenarios and impact mitigation strategies, using the FREFLO, Level II urban arterial, and TRAFFIC portions of the TRAFLO package as well as the TRANSYT-7F arterial network signal optimization program (46).

A series of menus were designed to guide the user through selections of the types of scenarios and strategies to evaluate. Once a particular strategy or scenario was selected, CARHOP adjusted the input database, interfaced the data between the TRAFLO and TRANSYT-7F programs as needed, and provided output statistics summarizing the results of the simulation.

The application of CARHOP as a planning analysis tool was demonstrated using a section of I-5 in Orange County, CA. Extensive reconstruction is underway or being planned along a considerable portion of I-5. However, the section examined in the demonstration is still very early in the planning stage and will most likely not undergo reconstruction until sometime in the 1990's. The demonstration site is a six-lane section carrying between 85,000 and 125,000 vehicles per day (as of 1985). CARHOP was used to investigate a series of reconstruction scenarios and mitigation measures, including (1) single-versus multi-lane closures, (2) traffic diversion to alternative routes, and (3) short versus long lane closure lengths. The results of the demonstration study are documented in a final report by ITS (49). The conclusions of the authors were that "The analysis . . ., while not necessarily an excellent indicator of operating conditions in an absolute sense, offers a reasonable basis for evaluating the relative merits of various strategies . . ." (49)

The most time-consuming task associated with the demonstration study was the development and calibration of an origin-destination trip table to be used by the TRAFFIC assignment model to simulate diversion away from the freeway due to the capacity restrictions imposed. The researchers were forced to take an origin-destination matrix for the entire Statistical Metropolitan Statistical Area and reduce it to the size and detail necessary for the demonstration study. It was estimated that the total calibration effort took about 1 year to complete, including almost 40 calibration simulation runs requiring several hours of CPU time each (49). However, there were limitations in the earlier version of the TRAFFIC model used in that study. The latest version has been improved significantly in terms of its analysis capabilities and computing efficiency.

Although CARHOP provides a mechanism for quickly and transparently modifying the input database for a variety of analysis scenarios, the creation of the initial database must still be done manually, a process that is one of the biggest drawbacks of simulation. The ongoing development of (1) preprocessors to aid in the initial creation of databases, and (2) interface programs to allow simulation models direct access to standard roadway and traffic databases will undoubtedly lead to better and more efficient use of simulation tools in the future.

Aoprooriateness for Reconstruction Project Travel Impact Evaluation

FREQ, TRAFLO, and INTRAS all provide methods of analyzing a wide array of reconstruction and impacts mitigation strategies at various levels of sophistication. Consequently, these types of models may be useful in determining the relative merits associated with various traffic management strategies. The output provided may be useful both for ranking and selecting appropriate strategies and for obtaining order of magnitude estimates of their expected effectiveness. However, the output values obtained are probably not extremely accurate or usable in an absolute sense.

While the models differ in terms of the type and amount of data needed, all require considerable effort for coding a network, entering demand volumes, and modifying the code for each alternative strategy of interest. As computer technology advances to the point that this data input step can be reduced, the potential for using simulation to predict and evaluate the travel impacts of reconstruction will be enhanced dramatically.

Urban Arterial Network Models

Application and Purpose

In most urban areas, streets and highways form an interconnected network where changes in conditions in one part affect operations throughout. Several simulation models have been developed to deal explicitly with arterial network operations, and many of them have been reviewed in other publications (25, 27) 50). This review will focus on two models for urban arterial network analysis: NETSIM and TRAFLO.

NETSIM (NETwork SIMulation), part of the TRAF system of computer simulation models being developed for FHWA, is a detailed, microscopic, stochastic model of traffic in an urban network. The model relies on complex car-following, lane-changing, and queue discharge algorithms to process traffic through the network being modeled, and gathers and maintains operational statistics throughout (24). NETSIM has the capability to evaluate a wider variety of geometric characteristics, traffic management strategies and dynamic (real-time) traffic control systems than macroscopic techniques can evaluate. In addition, NETSIM can realistically analyze oversaturated intersections and subsequent queue spillback.

The TRAFLO model was discussed in detail in the previous section on freeway corridor simulation models. In addition to its use in freeway corridor analysis, TRAFLO can be used to evaluate urban arterial networks, and so is included again in this section.

Use

Urban arterial network simulation models provide a means of examining the effect of expected travel pattern changes and proposed impact mitigation strategies upon traffic operations within the network. The analysis is complex, which is necessary for realistically examining closely-spaced traffic signals, evaluating the effectiveness of improved signal progression, or simulating the effects of non-intersection improvements to urban arterials, such as the removal of on-street parking or changing to alternating one-way streets.

Table B-3 summarizes some of the uses of the arterial network simulation models in evaluating highway reconstruction projects. As with freeway corridor simulation models, time-varying demands or temporary changes in roadway characteristics can be analyzed with either the NETSIM or one of the TRAFLO models by dividing the simulation period into incremental time slices of constant demand and roadway characteristics. Both NETSIM and TRAFLO Level I models can be used to examine the effects of turning bay lengths, curb radii, various driver/vehicle attributes, approach grades, and actuated traffic signals. NETSIM also has the ability to model traffic surveillance capabilities, short-term events (such as blockages due to illegal parking during deliveries), and parking activity.

Limitations

Limitations of urban arterial network models are primarily of two types: (1) the types of intersection control that can be evaluated, and (2) the size of the network that can be evaluated. Both TRAFLO and NETSIM are capable of analyzing sign-controlled and signalized (both fixed-time and traffic-actuated) intersection operations, although the analysis of traffic-actuated signals is somewhat limited in the TRAFLO model. Also, both models are capable of examining time-varying demand. NETSIM is limited, however, in the size of the network it can evaluate efficiently, due to its microscopic treatment of traffic movements throughout the network. Physical constraints are reported to be 99 nodes, 160 links, and 1600 vehicles present within the system at any time. These limits can be increased, but only with substantial increases in computer processing requirements. Network size does not appear to be a significant limitation for TRAFLO. There are trade-offs, however, between the amount of the network represented by each model, and processing time. Level I processing requirements are most extensive, although they are still less than those of the NETSIM model. It appears almost any practical size network can be analyzed through proper partitioning and representation using Levels I and II.

TABLE B-3. SOME USES OF URBAN ARTERIAL NETWORK SIMULATION MODELS

Evaluate the Impacts of:	TRAFLO I	TRAFLO II	NETSIM
Installing Signal Control at an Intersection	Yes	Limited	Yes
Signal Timing Changes:			
- Pretimed Signals	Yes	Yes	Yes
- Traffic-Actuated Signals	Limited	No	Yes
Left-Turn Restrictions	Yes	Yes	Yes
Minor Roadway Widening	Limited	Limited	Yes
New or Expanded Bus Service	Yes	Yes	Yes
Removal of Parking	Limited	Limited	Yes
Reversible Lanes	Yes	Yes	Yes

Data Requirements

Generally speaking, urban arterial network models require information about:

- o Each intersection in the network (node data): geometrics (permissible turning movements, channelization); saturation flow rates; signal phasing and timing settings
- o Roadways between intersections (link data): roadway lengths; geometrics (number lanes, grades, saturation flow rates); free-flow speeds
- o Traffic Characteristics: traffic volumes, turn percentages; vehicle distributions

There are significant differences between the TRAFLO Level I and II requirements, and data input can be minimized by a prudent subdivision of the network.

Typical Output

Output reports for both TRAFLO and NETSIM consist of:

1. Intermediate Link Statistics
   * vehicle movements
   * vehicle queues
   * vehicles discharged from link
   * control device indications

2. Cumulative Link and Subnetwork Statistics
   * vehicle-miles and vehicle-trips
   * move time, delay time, total time
   * average delays and speeds
   * percent stops and percent storage
   * cycle failures (oversaturation)

3. Cumulative Link-Specific Person Statistics
   * person miles, trips, delay, travel time

4. Cumulative Link-Specific Statistics by Turning Movements (NETSIM only)

5. Bus Statistics by Link
   * bus trips and person trips
   * move time, delay time, and total travel time
   * average speed
   * number of stops

6. Fuel Consumption and Vehicle Emission Statistics (Optional)

Advantaaes and Disadvantaaes

Table B-4 summarizes the advantages and disadvantages of the urban arterial network models. The major advantages of NETSIM and TRAFLO are their ability to explicitly simulate (1) stop-sign-controlled or signalized intersection (isolated or coordinated) operations, and (2) time-varying traffic demands. Traffic-actuated signals are probably best simulated using NETSIM, however. Also, other possible TSM strategies, such as improved intersection channelization, can be modeled by TRAFLO or NETSIM. The primary disadvantages of these models are that they require fairly large amounts of data (especially NETSIM) and that they do not have explicit signal optimization routines. However, several signal optimization programs do exist (see traffic optimization section later in this report) that can be used to develop signal timing settings that can then be input into TRAFLO or NETSIM for evaluation.

Aoorooriateness for Reconstruction Project Travel Impact Evaluation

Both TRAFLO and NETSIM may have application in the travel impact evaluation process for reconstruction projects. In some cases, NETSIM will be more appropriate, such as for analysis of traffic-actuated signal equipment and traffic surveillance capabilities at key intersections. In other cases, it may be reasonable to simulate the urban arterial network with TRAFLO and save considerable time and effort in data input and computer processing.

Freeway Corridor Assignment Models

This section provides a brief overview of a freeway corridor assignment model PASSER-IV (52). This model provides a method of estimating travel pattern changes in a freeway corridor due to freeway reconstruction. The program is not widely available at this time, but has some unique features which may be useful in the analysis of certain types of major highway reconstruction. The TRAFLO program, with its TRAFFIC assignment program, should also be considered in this section; but since its principal features have been documented in the previous sections, only those aspects of TRAFFIC not previously mentioned are discussed here.

TABLE B-4. ADVANTAGES AND DISADVANTAGES OF URBAN ARTERIAL NETWORK SIMULATION MODELS

	TRAFLO	NETSIM
ADVANTAGES	Time-Varying Demand can be Modeled Limited Traffic-Actuated Signal Analysis Capability Available (with Level I) Can Customize Network Representation to Fit Needs and Reduce Computer Time	Time-Varying Demand can be Modeled Traffic-Actuated Signals can be Modeled Detailed Treatment of Traffic Detection and Surveillance, Parking and Pedestrian Effects
DISADVANTAGES	Large Data Requirements No Explicit Signal Optimization	Large Data Requirements Long Computer Processing Times No Explicit Signal Optimization

Aoolication and Purpose

A quick-response corridor assignment program, PASSER-IV, was developed by researchers at the Texas Transportation Institute. The program performs an equilibrium assignment of an overall hourly corridor traffic demand to the freeway and up to ten alternative routes. These assignments are based on estimates of travel times from piece-wise linear relationships as a function of volume/capacity ratio (and traffic signal density on each non-freeway route). The program is not supported by either the Texas Transportation institute or the Texas State Department of Highways and Public Transportation but documentation and the source code are available (53).

Use

PASSER-IV and TRAFLO could be used to predict the impact of various major traffic management strategies (such as freeway lane closures) and some impact mitigation measures on alternative routes upon corridor travel patterns. Table B-5 summarizes some of the uses of these models for reconstruction planning and analysis. For each model, however, the extent of several of the uses indicated in Table B-5 is limited, and is modeled only by adjusting the link capacities.

Limitations

The level of analysis provided by PASSER-IV is extremely limited; the model does not consider the effects of different driver origins or destinations, ramp locations, or signal timing characteristics in its assessment of travel times on the various routes. It is also limited to analysis of a single directional freeway corridor segment. The TRAFFIC assignment model of TRAFLO allows for a redistribution of traffic over a corridor or an entire region due to major changes in link capacities.

Data Requirements

Input data for PASSER-IV consists of link data for the freeway and alternative routes in the corridor (number of lanes, link lengths, speeds, capacities), signal density (number per mile) on the alternative routes, existing traffic density on the alternative routes, and total hourly corridor traffic demand.

The data requirements for TRAFLO have been discussed earlier.

TABLE B-5. SOME USES OF FREEWAY CORRIDOR ASSIGNMENT MODELS

Evaluate the Impacts of:	PASSER-IV	TRAFLO
Permanent Lane Closures, Ramp Closures, or Lane Drops	Limited	Yes
Reduced Lane/Shoulder Widths	Limited	Limited
Minor Changes in Geometrics	Limited	Limited
Ramp Metering	No	Yes
HOV (Priority) Lanes	No	Yes
Temporary Lane Closures, Ramp Closures, or Incidents	No	Yes
Surveillance and Control	No	Yes
Diversion (Traffic Reassignment)	Limited	Limited
Consideration of Changes on Alternative Routes	Limited	Limited

Typical Output

PASSER-IV output is very simple, limited to an estimate of equilibrium travel time for the freeway and alternative routes (the estimated time will be equal on all routes) and estimates of traffic volumes and corresponding volume/capacity ratios for each of the routes. TRAFLO outputs have been discussed in the previous sections.

Aooropriateness for Reconstruction Project Travel Impact Evaluation

PASSER-IV and TRAFLO provide a means of estimating the redistribution of traffic volumes resulting from changes in capacity on the freeway due to reconstruction. The equilibrium assignment methodology for PASSER-IV may be inappropriate for all but the most major changes in capacity within the corridor. The TRAFFIC assignment model of TRAFLO has been used in a demonstration study for evaluating the impacts of major freeway reconstruction. Its use in future analysis appears justified, although more research and experience with the model is needed.

TRAFFIC OPTIMIZATION MODELS

Along most urban arterials, signalized intersections are the primary restrictions to the flow of traffic, resulting in stops, delays, and a general degradation of traffic conditions throughout the arterial network. Because of the major impact that signalization has upon the overall efficiency of traffic movement, considerable effort has been devoted to the development of procedures to optimize traffic signal operations so as to best utilize the capacity of these intersections. A number of programs are available to aid the traffic engineer in the development of optimized signal phasing and timing plans. This review summarizes the characteristics of these various programs and their potential application before and during major highway reconstruction projects.

Aoolication and Puroose

One of two optimization criteria are commonly used for traffic signalization. The first is the minimization of delays and stops, while the second is the maximization of progression (bandwidth) between signals. Delay minimization is appropriate for analyzing either individual intersections or a series of intersections, while progression maximization is appropriate when considering the coordination of a series of intersections.

Among the programs for single intersection optimization, SOAP (Signal Operations Analysis Program) (54) is one of the most well-known and documented tools available. The program can be used for developing optimum signal timing plans and optimal cycle lengths for both fixed-time and traffic-actuated signals. Deterministic, mathematical relationships derived from Webster's equations (55) are used to estimate delay.

At the next level of sophistication are programs for minimizing delay and stops throughout a network of intersections, TRANSYT-7F and SIGOP III (56.57) are both well-accepted traffic engineering tools for this purpose. These programs are significantly more complicated than the single intersection programs, since they must consider the interaction of signal timing (green splits), cycle length, and timing offsets between signals, searching for the combination that minimizes delays and stops throughout the network. The models are also deterministic, based on Webster's delay equation.

Bandwidth maximization programs also search for the optimum signal timing and offset combinations for signals along an arterial or limited network, but with emphasis on providing the best traffic progression from signal to signal. The principal programs of this type are PASSER II (58) and MAXBAND 86 (59) PASSER II has been widely used for optimizing bandwidths for signals along a single linear arterial, and has been incorporated into the Arterial Analysis Package developed and maintained by FHWA (60). MAXBAND 86 is based on mixed- integer linear programming techniques that allow for bandwidth optimization over generalized grid networks. These two programs have the added capabilities of considering different phase sequences in the search for the optimum signal settings.

Use

Often, major highway reconstruction will cause a significant change in travel patterns on the surrounding arterial street system. It may be necessary to adjust traffic signal timings at some locations in order to accommodate the travel pattern changes and provide the best operations possible during reconstruction. Another potential use of these models would be to encourage traffic to divert from the highway being reconstructed by changing the signal timings to deliberately give preference to travel movement along thealternative routes. Table B-6 summarizes some potential specific uses of traffic optimization models in the traffic impact evaluation process. For some of the uses listed in Table B-6, explicit analysis is not possible. Instead, the user must modify items such as permissible phase sequences, saturation flows, or average speeds to reflect the effects of left-turn restrictions, parking restriction, or reversible lanes.

Limitations

As with all types of models and programs for traffic analysis, the results obtained with traffic signal optimization programs are only as good as the data used to obtain those results. It is quite difficult to predict actual changes in traffic volumes at a specific intersection due to major roadway reconstruction somewhere within the corridor, and so suggested signal timing changes based on these estimates could be quite sub-optimal if implemented, depending on how estimated volume changes compare to the actual changes that occur. However, signal optimization programs could be useful in estimating to what extent hypothetical changes in traffic volumes could be accommodated by signal timing changes throughout the roadway system.

TABLE B-6. SOME USES OF TRAFFIC OPTIMIZATION MODELS

Evaluate the Impacts of:	SOAP	TRANSYT-7F	SIGOP III	PASSER II	MAXBAND 86
Optimized Signal Timing					
-Isolated Intersection	Yes	Yes	Yes	Yes	Yes
-Linear Arterial or Open Network	No	Yes	Yes	Yes	Yes
-Arterial Network	No	Yes	Yes	No	Yes
Favoring a Particular Traffic Direction on an Alternative Route	N o	Yes	Yes	Yes	Yes
Left-Turn Restrictions	Yes	Yes	Yes	Yes	Yes
New or Expanded Bus Service	No	Limited	No	No	No
Removal of Parking	Limited	Limited	Limited	Limited	Limited
Reversible Lanes	Limited	Limited	Limited	Limited	Limited

Data Reauirements

Data for most signal optimization programs consists of three main types: (1) traffic volumes, (2) signal controller information, and (3) basic geometrics including the relative location of intersections and descriptions of the arterial segments. Generally speaking, bandwidth maximization programs, such as PASSER II and MAXBAND 86, require slightly less information than the delay minimization programs like TRANSYT-7F and SIGOP Ill. In fact, PASSER II and MAXBAND 86 may be run without any traffic data if the user can supply the green times necessary for each phase. Delay minimization programs consider the time-dependent nature of traffic movement from intersection to intersection in slightly more detail and model certain types of traffic behavior, such as platoon dispersion, explicitly. In addition, TRANSYT-7F and SIGOP Ill also have explicit simulation capabilities, which require more information.

Typical Output

Signal optimization programs typically provide optimized signal settings for intersections, estimates of traffic performance characteristics along the arterial, and time-space diagrams to aid the user in visualizing travel flow along the arterials. MAXBAND 86 and PASSER II provide more information relative to bandwidth maximization (such as progression efficiency and attainability), while TRANSYT-7F and SIGOP Ill provide more details about traffic conditions on both the intersections and the individual links in the network (average speeds, total travel, delays, headways).

Advantaaes and Disadvantaaes

Table B-7 summarizes the major advantages and disadvantages of the traffic optimization models. Bandwidth maximization programs are fairly easy to learn, require only a limited amount of input, and provide signal timing plans optimized for progression. In addition, the programs discussed (PASSER II and MAXBAND 86) can consider different cycle lengths and phase sequences in a single optimization run. PASSER II is limited in that it can only optimize linear atterials and open networks, whereas MAXBAND 86 can optimize progression in a network (although at a high cost in computer time).

While TRANSYT-7F and SIGOP Ill require a little more data and time to learn, they allow the user explicit control over certain model parameters (such as platoon dispersion coefficients). Also, these programs optimize signal settings based on a minimization of stops and delays for those who wish to base their signal timings on such factors.

TABLE B-7. ADVANTAGES AND DISADVANTAGES OF TRAFFIC OPTIMIZATION MODELS

	SOAP	TRANSYT-7F	SIGOP III	PASSER II	MAXBAND 86
ADVANTAGES	Easy to Use	Limited Traffic Simulation Capabilities	Limited Traffic Simulation Capabilities	Easy to Use	Easy to Use
	Low Data Requirements	Explicit Control over Certail Traffic Model Parameters	Explicit Control over Certain Traffic Model Parameters	Low Data Requirements	Low Data Requirements
				Explicit Analysis of Phase Sequencing	Explicit Analysis of Phase Sequencing
DISADVANTAGES	Limited to Isolated Intersections	Larger Data Requirements	Larger Data Requirements	Limited to Linear Arterial or Open Network	Long Computer Processing Times
		Cannot Consider Different Phase Sequences	Cannot Consider Different Phase Sequences		

Appropriateness for Reconstruction Project Travel Impact Evaluation

Signal optimization programs appear to be useful for determining the ability of alternative routes to accommodate diverting traffic or other changes in travel patterns that may result from reconstruction. The models provide optimized signal timing plans and resulting traffic conditions on the arterials or throughout the network with a minimum amount of time, effort, and data. Consequently, a wide range of possible travel pattern changes can be investigated quickly and easily. The models would also be quite appropriate throughout the reconstruction process to modify signal timing plans along the travel routes in response to travel pattern changes so as to maintain the best level of service and corridor traffic flow possible.

APPENDIX C

REVIEW OF MAJOR HIGHWAY RECONSTRUCTION PROJECTS IN FIVE CITIES

This appendix contains detailed reviews of the planning efforts for five major highway reconstruction projects:

- I-376, Penn-Lincoln Parkway East, in Pittsburgh
- I-93, Southeast Expressway, in Boston
- I-76, Schuylkill Expressway, in Philadelphia
- US-IO, John C. Lodge Freeway, in Detroit
- I-394 in Minneapolis

The reviews summarize the planning efforts undertaken, the traffic management strategies employed, and the actual travel impacts observed in each project. The objective is to highlight the experiences gained and lessons learned from the projects.

I-376, PENN-LINCOLN PARKWAY EAST, PITTSBURGH

The reconstruction of the Parkway East was the first project in which the Federal Highway Administration (FHWA) approved the use of Interstate funds for efforts to mitigate the off-system impacts of Interstate reconstruction. Since it was the first such project, the Pennsylvania Department of Transportation (PennDOT) and FHWA sponsored a study to monitor and evaluate the traffic characteristics, the responses and attitudes of travelers in the affected corridor, and the effectiveness of the impact mitigation strategies. The findings of the study have been thoroughly documented in a six volume report (5) and in several related articles (61, 62).

The Parkway East is the only major east-west freeway connecting the Pennsylvania Turnpike (I-76) and eastern suburban communities with downtown Pittsburgh. The corridor is illustrated in Figure C-l. The facility is a four-lane freeway, including the 0.8 mi double-bore Squirrel Hill Tunnel. It carries 130,000 vpd through the section being rehabilitated, including 80,000 vpd through the tunnel. PennDOT undertook a $62 million reconstruction and safety update project on a 6.5 mi section of the Parkway during the construction seasons (March through October) of 1981 and 1982. Work included (1) an 8 in concrete pavement overlay, (2) rehabilitation of 21 bridges, (3) new lighting and ventilation in the tunnel, and (4) new signing and high mast lighting.

Planning Process

Planning for the Parkway East project began in 1979, approximately two years before reconstruction began. Early in the planning process it was recognized that the potential existed for severe traffic disruptions due to the reconstruction project. The decision was made to maintain one lane of traffic in each direction through the reconstruction period. This made it necessary to spread the work over two full construction seasons (March through October). It was also decided to close most of the entrance ramps within the reconstruction zone.

Another problem that had to be dealt with was the lack of high-speed, high-capacity, parallel alternative routes. The only viable alternative routes were arterial streets, many of which were already congested. This led to a focus in the planning effort on strategies to move people rather than vehicles. A series of brainstorming sessions were held to identify strategies that had a reasonable likelihood of being successful. The emphasis was on strategies to divert trips to transit, Carpools, and Vanpools and to increase the

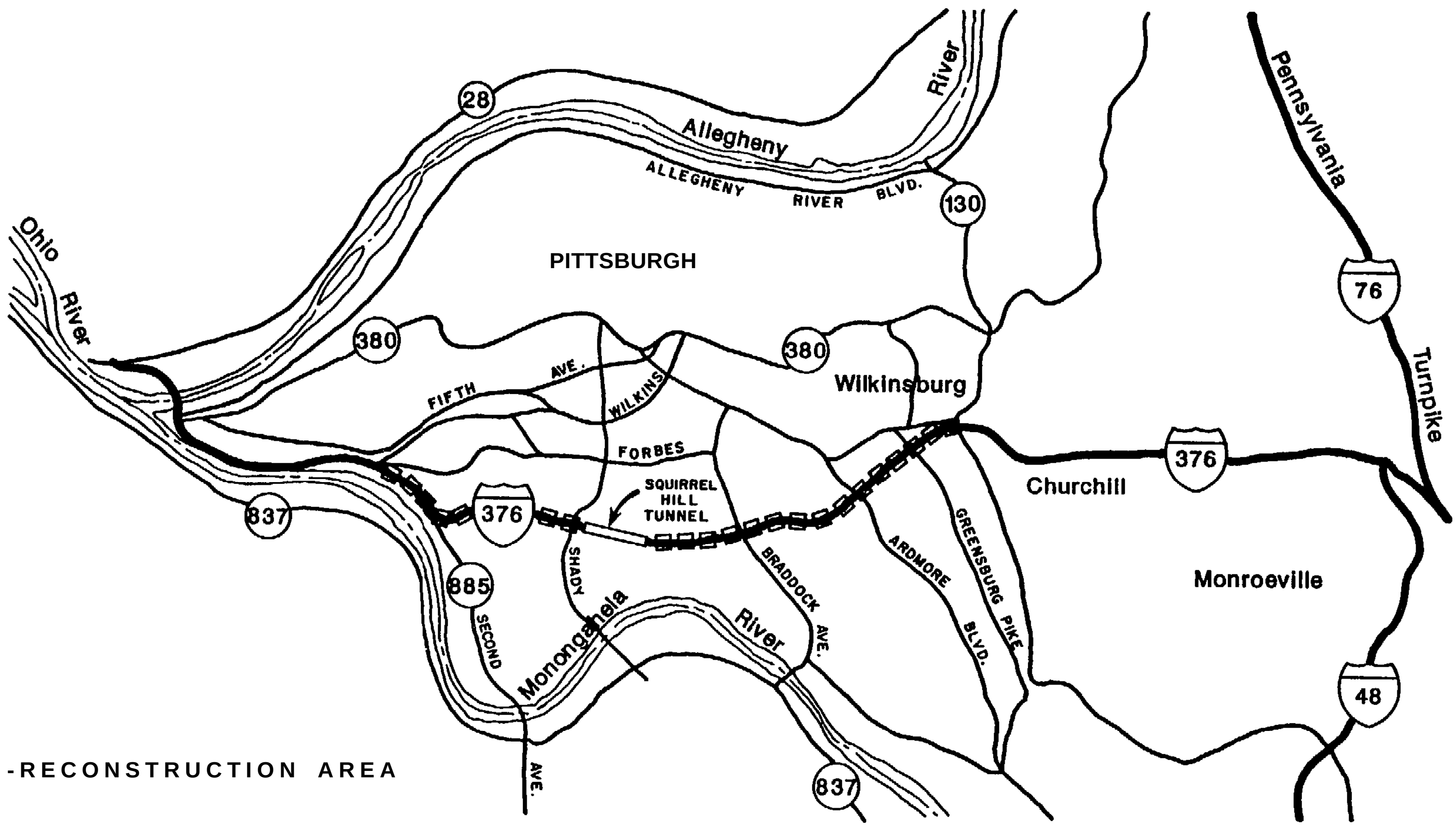

Figure C-l. Map of the Parkway East Reconstruction Project Corridor in Pittsburgh capacity of alternative routes. It must be recognized that the Parkway East project was among the first to employ such an approach. Therefore, project planners had little precedent to aid them in deciding what to do.

With the basic traffic management strategies in mind, PennDOT employed the services of the Southwestern Pennsylvania Regional Planning Commission (SPRPC) to predict the travel impacts of the Parkway East reconstruction project and to analyze the effectiveness of the various impact mitigation strategies. The SPRPC maintains the regional travel model for the Pittsburgh region. They used existing travel demand forecasts and applied quick-response estimation techniques in their analysis.

The SPRPC started with existing estimates of 1978 zonal trip production and attraction rates which they aggregated to a district level. (The region was divided into 15 districts for the analysis.) Trips were categorized as home-based work, home-based non-work, and non-home based. It was assumed that the number of trip productions and attractions by district would not change during reconstruction.

NCHRP Report 187 (8) quick-response estimation techniques were used to estimate trip distributions between districts by trip purpose. Trip distribution patterns for both before- and during-reconstruction periods were estimated. District-to-district travel times for the before period were estimated using the NCHRP 187 procedure. Before-period travel times were adjusted to account for the increased travel times during reconstruction. The during period travel times did not account for any improvements that might be made to alternative routes. It was assumed that only non-work trip interchanges would be affected by the project. That is, it was assumed that people would not change jobs or move their households because of the increased travel times during reconstruction. A comparison of the predicted trip distribution patterns before and during the project suggested that non-work trips would avoid the Parkway and would remain closer to home.

Next, an analysis of mode split and auto occupancy was performed to estimate the changes in mode usage that would result from the project. Again, NCHRP Report 187 quick-response estimation procedures were used. Auto and transit person-trip tables as well as vehicle-trip tables were estimated for both the before- and during-reconstruction periods. Before-period estimates were compared with existing home interview survey results and screenline counts to calibrate the results. During-period estimates assumed that no improvements were made to alternative routes. A comparison of before and during estimates indicated a 12.9% reduction in traffic crossing the screenline. This reduction was due in part to the predicted redistribution of non-work trips and in part to an estimated 14 percent increase in transit usage. The results indicated a potential for as many as 2700 additional transit riders during the peak period, primarily between the easternmost districts and the downtown area.

Several analyses were performed to estimate the impact of the strategies to divert trips to Carpools, Vanpools, bus, and commuter rail. The impacts were measured in terms of the percentage reduction in the total traffic volume across the screenline.

No attempt was made to estimate the number of people that would divert to carpooling. Rather, the reductions in traffic volumes associated with assumed percentages of people who drove alone diverting to Carpools were estimated. It was assumed that only trips whose destination was downtown Pittsburgh, with its high employment density, would divert to carpooling.

The potential diversion to Vanpools was estimated using existing survey data on downtown employees. Persons who worked downtown, lived in the Parkway East corridor, and were interested in vanpooling were identified and their locations analyzed to determine the demand for additional Vanpools. The SPRPC estimated, based upon their existing data on the modes currently used by people interested in vanpooling, that each 15-passenger van would replace five automobiles.

The impact of measures to improve bus service was estimated by translating the 2,700 additional bus riders during reconstruction that were estimated in the mode split analysis to an equivalent number of vehicles.

The impact of providing commuter rail was estimated based upon the capacity of the planned service. There was no attempt to predict the number of people that would actually use the service.

Traffic Management Strategy

The basic traffic management strategy employed during most of the project was to close both lanes in the affected direction (inbound in 1981 and outbound in 1982) and to maintain two-lane, two-way traffic in the other direction. The entrance ramps within the reconstruction zone were closed and the entrance ramp nearest each end of the reconstruction zone was restricted to high-occupancy vehicles. Individual exit ramps were closed when work activities made it necessary.

The closure of one direction of the freeway reduced its capacity by more than 50 percent and the closure of entrance ramps restricted access. As a result, many motorists were forced to divert from the Parkway East. The only alternative routes were arterial streets, many of which were congested before the restrictions were imposed on the Parkway. Therefore, a plan of people-moving strategies was implemented both to improve alternative routes and to provide alternative modes of travel. The approved cost of the plan was more than $11 million, although only $4.8 million were actually spent.

The people-moving strategies, referred to as the "Pittsburgh Experiment," included:

- Instituting a new commuter train that operated between Pittsburgh's eastern suburbs and central business district
- Contracting with a third-party Vanpool coordinator to organize vanpooling in the eastern suburbs
- Contracting with the local transit authority to add several express bus routes in the corridor
- Restricting entrance ramps to the Parkway at both ends of the reconstruction zone to high-occupancy vehicles
- Arranging with several property owners in the eastern suburbs to use existing parking lots as new park-and-ride lots for express bus passengers, carpoolers, and vanpoolers
- Making traffic operations improvements on several alternative routes in the corridor

Actual Travel Impacts

An extensive data collection program was implemented to measure the changes in traffic patterns, motorist impacts, and level of usage of the alternative transportation strategies. The data collected included:

- Hourly and daily traffic counts at forty locations along one full and three partial screenlines before, during, and after the first construction phase in 1981 and at six locations during and after the second construction season
- a.m. peak period vehicle occupancy and classification counts before, during, and after the first construction season.
- a.m. peak, off-peak, and p.m. peak period travel times on the Parkway and five alternative routes before, during, and after the first construction season
- Traveler responses to questionnaires with information including trip origins and destinations, and individuals' changes in departure time, route, and mode of travel

- o Ridership or user counts on the new commuter train, Vanpools, express buses, and park-and-ride lots

In response to the traffic restrictions, the total volume of traffic entering the Parkway East reconstruction zone decreased by 60 percent from 132,000 vpd before reconstruction to 52,000 vpd during. Morning and evening peaks were nearly eliminated. Through the Squirrel Hill Tunnel, for example, the morning peak hour volume dropped by almost 70 percent. However, the counts along the complete screenline, which included all major highways in the corridor and which cut through the center of the reconstruction zone, decreased by only 1.5 percent during the first construction season. These counts, in conjunction with other data, indicated that the most common response by motorists was to continue to drive their automobile but to use alternative routes in the corridor.

The complete screenline included counts on the Parkway as well as on 16 other major highways in the corridor. The diverted traffic was concentrated on the arterial streets closest to the Parkway; increased volumes on the six parallel arterial streets closest to the Parkway accounted for more than 60 percent of the decrease in volume on the Parkway.

The traffic operations improvements to alternative routes in the corridor were intended to increase capacity and reduce congestion. The improvements included signal installation, coordination, and other improvements; left-turn prohibitions; parking restrictions; pavement widening; signing and pavement marking; and the stationing of traffic control officers at critical intersections during peak periods.

Overall, during the first construction season, travel times on the Parkway increased by 9 min (30 percent) inbound during the a.m. peak and by 20 min (154 percent) outbound during the p.m. peak. Average travel times throughout the whole corridor increased by 16 percent inbound during the a.m. peak and by 57 percent outbound during the p.m; peak. Travelers accommodated these increases with departure times that averaged 20 min earlier during reconstruction.

Use of the alternative transportation strategies varied. The new commuter train carried far fewer passengers than had been anticipated; the average daily ridership which was more than 600 at the beginning of the project declined to less than 400 by the end of the first construction season. As a result, the commuter train service was discontinued in November 1981 and was replaced by express bus service. The average of 500 passengers per day using the commuter train during the first construction season was estimated to represent a reduction of 200 vehicle trips on the Parkway East.

Six express bus routes operated during the first construction season and a seventh was added during the second season to replace the commuter train. The routes were changed several times in response to demand. The average weekday ridership was about 1,400 during the first season and 1,500 during the second season which represented a diversion of 500 vehicle trips from the entire corridor and more than 300 vehicle trips from the Parkway East.

The Vanpool program operated 18 Vanpools, representing more than 600 passenger trips, during the first season and as many as 34 Vanpools, representing nearly 1000 passenger trips, during the second season.

The park-and-ride lots were coordinated with the express bus service and Vanpool program. Initially, twelve existing parking lots were designated as new park-and-ride lots to supplement the 10 lots that had been in use before reconstruction. Five of the twelve new lots were discontinued during the first construction season due to low usage.

The high-occupancy vehicle ramps were intended to promote ridesharing by reducing travel times for authorized users. It was estimated that use of the ramps reduced average total travel times by 8 minutes.

In summary, in spite of a more than 50 percent reduction in the capacity of the Parkway East, the only major freeway between the eastern suburbs and downtown Pittsburgh, the transportation system in the corridor handled traffic remarkably well. Significant traffic diversion away from the Parkway did occur during the reconstruction project; 60 percent fewer vehicles per day entered the Parkway reconstruction zone. However, the total traffic on all routes in the corridor decreased only slightly. The most common motorist response to the reconstruction was to change to alternative routes and to depart earlier. The ridesharing options that were provided and promoted accounted for only about 20 percent of the vehicles diverted from the Parkway during the peak hour. Therefore, the traffic operations improvements to alternative routes were deemed the most effective means of accommodating the traffic diverted from the reconstruction zone.

I-93, SOUTHEAST EXPRESSWAY, BOSTON

I-93, Southeast Expressway, is the only major highway facility connecting Boston with southeastern Massachusetts. Figure C-2 illustrates the Southeast Expressway corridor. The Expressway is a six-lane freeway facility with a breakdown lane in each direction used as a travel lane during peak hours. It carried more than 160,000 vpd before reconstruction. A reconstruction project was undertaken by the Massachusetts Department of Public Works (MDPW) on an 8.5 mile section of the Expressway during the construction seasons (March through November) of 1984 and 1985 to (1) replace bridge decks and resurface the roadway, (2) widen and lengthen merge areas at ramps, (3) improve lighting and signing, and (4) alleviate drainage problems. The experiences from the project have been thoroughly documented (63).

Project Planning

Planning for traffic management during reconstruction began in early 1983, approximately one year before the project started. The planning analysis was performed in-house by the Central Transportation Planning Staff, which is the technical planning staff for Boston's Metropolitan Planning Organization, of which MDPW is a part.

Meyer (64) describes the planning analysis that was done for the project:

> Several technical analyses were undertaken for the Expressway project, which resulted in 22 technical reports. However, the analysis methodology for these efforts was uncomplicated, relying heavily on origin-destination data from previous surveys and on highway capacity analysis procedures. No effort was made to predict, through demand estimation techniques, which alternatives would be most likely to be. used by Expressway commuters. Instead, capacity analyses were undertaken on alternate routes and modes to determine their additional carrying capacity and to identify key bottlenecks or constraints to handling additional demand. This analysis approach fit closely the overall philosophy of the planning effort that was to provide as much additional capacity as possible.

Because of the importance of the Expressway, the MDPW made a policy decision to maintain as much capacity on the Expressway during reconstruction as possible. It was decided to divide the Expressway into four two-lane segments and to work on only one two-lane segment at a time. One two-lane segment was provided for each direction at all times and the remaining segment was reversible. This provided four lanes in the peak direction, the same number as before reconstruction, and two lanes in the

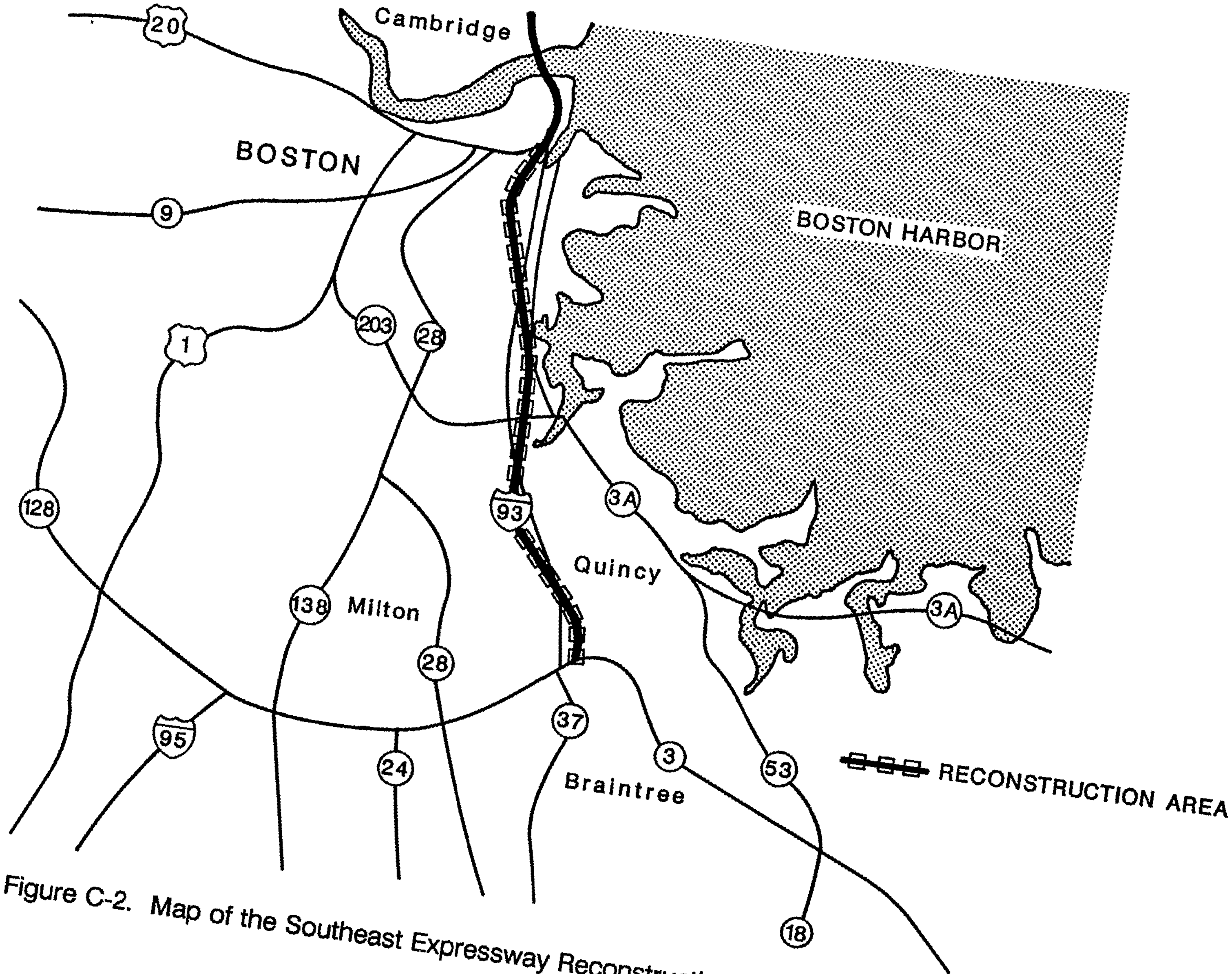

Figure C-2. Map of the Southeast Expressway Reconstruction Project Corridor in Boston off-peak direction. Screens were installed on the sides of the work area to minimize potential reductions in capacity resulting from motorist rubbernecking. In addition, the MDPW developed a plan of impact mitigation strategies to minimize the disruption to Expressway users during reconstruction.

When the planning for the traffic management and impact mitigation strategies during reconstruction began in early 1983, the design and the traffic control plan for the project were still being finalized. The first step in the planning process was to develop estimates of the capacity of the Expressway before and during reconstruction.

The capacity of the Expressway before construction had been estimated in an earlier study and those estimates were used in the planning process. The normal cross section of the Expressway consisted of three, 13-ft travel lanes and one 10-ft breakdown lane. The breakdown lane was used as a travel lane only during peak periods in the peak direction. The peak period capacity, with the breakdown lane, was estimated to be 7,400 vph (or 1,850 vph per lane) in the peak direction. The off-peak capacity was estimated to be 5,850 vph (or 1,950 vph per lane) in the off-peak direction.

The capacity of the Expressway during reconstruction was estimated using the 1965 Highway Capacity Manual (65). Per-lane capacities were estimated based upon assumed lane widths and lateral clearances, since the final design during reconstruction had not yet been determined. The width of the two-lane segments varied between 22 and 24 ft, which would allow two, 11 or 12 ft lanes without shoulders. The segments would be separated by barriers. A question arose as to the effect of the restricted lateral clearances to the barriers. Some evidence exists that the effect of restricted lateral clearances to certain types of barriers may be minimal. It was assumed that, since most of the motorists on the Expressway were frequent users, the effect would not be as severe as estimated by the adjustment factors in the 1965 HCM. The resulting capacity estimates were 6,700-6,900 vph in the peak direction and 3,200-3,400 vph in the off peak direction. This represented a decrease in the capacity of the Expressway during reconstruction of 500-700 vph in the peak direction and 2,450-2,650 vph in the off-peak direction.

The next step in the planning analysis was to compare the capacities and traffic volumes during reconstruction. The analysis was based upon data from a permanent count station on the Expressway with some supplemental data from machine and manual counts. The volume data from the permanent count station indicated that there had been little growth in traffic over the last several years and that seasonal variations in traffic were minor. Therefore, the counts taken in April 1983 were used as the estimated traffic volumes during the 1984 and 1985 reconstruction period. It was determined that existing traffic volumes would exceed the capacity of the Expressway during reconstruction during certain times of day. Although some problems existed in the peak direction during the peak hours, the most severe problems occurred in the off-peak directions during the times when only two lanes were available. These results led to an analysis of the availability of capacity on alternative routes and on other modes in the corridor.

Potential alternative routes were divided into 47 two-way links. Existing traffic count data, which were available for 32 of the 47 links, were used to estimate the capacity of the links. The directional peak hour volumes (inbound and outbound) from the count data were used as an estimate of the capacity of the link in each direction. Hourly estimates of available, or unused, capacity inbound and outbound were computed as the difference between the estimated capacity and the directional hourly volume. Alternative paths, i.e., combinations of links, were identified. The available capacity of each path was estimated as the smallest available capacity of all links constituting the path. A comparison of the total available inbound and outbound capacity on the alternative paths to the excess volumes on the Expressway indicated that the alternative paths appeared to have sufficient capacity to accommodate the excess Expressway traffic except for one hour inbound in the morning peak and one hour outbound in the afternoon peak.

The analysis of the available capacity on alternative routes suggested four routes to which Expressway traffic would be most likely to divert. A subsequent analysis was performed to reassign the excess volumes on the Expressway to these alternative routes. The reassignment was done manually. Existing origin-destination data, from the Boston Central Artery 1977, Oriain- Destination Study, were used to determine (1) the number of Expressway trips from each originating zone and (2) most likely alternative route(s) for Expressway trips from each zone. This information was used to determine the percentage of excess Expressway volume that would be reassigned to each route.

The traffic reassignment analysis suggested that the capacities of three of the four alternative routes would be exceeded with the addition of the reassigned excess Expressway volumes. Therefore, a detailed field evaluation of these routes was conducted to identify problem areas caused by the diverted traffic and to collect data on each signalized intersection along each route. The data collected included signal timing and phasing, approach lane widths and utilization, and the location of parking and bus stops. These data were used to estimate the capacity of the signalized intersection approaches that would be used by diverted Expressway traffic. Hiahwav Capacity Manual (65) procedures were used to estimate the approach capacities. Estimated capacities were compared with traffic volume data to identify intersection approaches with capacity deficiencies. Those approaches on each route whose capacities were most restrictive were identified and evaluated, and improvements at those locations were recommended.

Analyses were also conducted to identify available capacity and likely demand for other modes in the corridor. Specific analyses were performed to analyze the capacity of the rail transit line in the corridor, the demand for park & ride lot spaces, and potential routes for express bus service. The philosophy of the MDPW in developing their impact mitigation strategy was "to provide a wide range of options for commuters (even though some of these options were not considered cost-effective), and then to cut back services that were not being used after 3 months" (64). Estimating modal shifts due to reconstruction impacts would have been difficult because of the limited time frame for planning and the limited information on how motorists respond to such impacts. The approach taken by MDPW eliminated the need to rely on potentially unreliable estimates and minimized the risk of implementing services that would be underutilized.

Traffic Management Strategy

The basic traffic management strategy was to maintain as much capacity on the Expressway as possible and to provide motorists with as many travel alternatives as possible. Because of the uncertainty in the planning analysis, it was decided to implement improvements on alternative routes and modes with the flexibility to discontinue strategies that were not utilized.

The actions that were actually taken to mitigate the adverse impacts of the reconstruction of the Southeast Expressway included:

- Providing increased commuter rail, boat, and bus service
- Increasing the number of park-and-ride lot spaces
- Supporting an employer-based ridesharing program
- Encouraging large employers to implement variable work hour or flextime programs
- Making traffic signal and pavement marking improvements at key intersections on alternative highway routes
- Placing police officers at certain intersections for traffic control
- Funding proposals from 15 communities to mitigate local traffic control problems resulting from the reconstruction project

- Providing an extensive public information and community liaison program

The total cost of the mitigating actions was $9 million. A key to the overall program was the flexibility to modify or discontinue actions as the need arose. For example, much of the additional bus service was discontinued after three months of operation because it had not attracted sufficient riders. Also, the number of intersections at which police were present was reduced to only those at which their presence was deemed effective.

Actual Travel Impacts

In order to evaluate the effectiveness of the mitigating actions, an extensive travel monitoring program was implemented. This program included travel time measurements and volume counts on the Expressway and alternative routes and motorist/transit rider surveys before, during, and after reconstruction.

The results of the travel monitoring program indicated that it took several weeks for commuters to experiment with alternative routes and decide how to adjust to the reconstruction project. This was evidenced by fluctuations in travel patterns during the first several weeks of the project, after which patterns stabilized.

It was estimated that during the first year between 5,000 and 9,000 vpd (3-6 percent of pre-reconstruction volumes) diverted from the Expressway, but that, during the second year, volumes returned to pre-reconstruction levels. Morning peak volumes were actually higher than pre-reconstruction levels. The distribution of morning peak period volumes indicated a shift to earlier departure times. The reductions in first year volumes occurred primarily during midday and afternoon peak periods. Officials speculated that this was due to the cancellation of discretionary midday trips.

Most of the diverting traffic apparently used the alternative highway routes in the corridor. The increase in volumes on the alternative routes was actually greater than the decrease in volumes on the Expressway during the first year. In addition, the use of the park-and-ride lots, commuter boat, and commuter rail service increased; some of these increases were attributed to improvements in service and not to the negative impact of reconstruction. Ridership on the rapid transit system was stable during the first year but declined during the second year, while use of the express bus service varied from route-to-route but, overall, declined slightly during reconstruction.

I-76, SCHUYLKILL EXPRESSWAY, PHILADELPHIA

The Schuylkill Expressway is the major east-west freeway connecting the Pennsylvania Turnpike (I-76) and western suburbs with downtown Philadelphia. Figure C-3 illustrates the corridor. The 21-mi long freeway is predominantly four-lane, although several segments near downtown have six or eight lanes. Traffic volumes range from 80,000 vpd near the Turnpike to 143,000 vpd near downtown. The Expressway was completed in 1961 and the deteriorating condition of both the pavement and bridge decks necessitated extensive reconstruction. The Pennsylvania Department of Transportation undertook a 3- year project to (1) rehabilitate 18 mi of pavement with a structural bituminous overlay, (2) rehabilitate 50 bridges by redecking 38 and overlaying 12, (3) widen shoulders, and (4) replace the existing metal guardrail in the median with concrete median barrier. Several articles have documented the project (66-68).

Project Planning

PennDOT was committed to completing the project as quickly as possible and with the least possible disruption to motorists. Planning began in November 1981, approximately three-and-one-half years before the start of the project. The top management of PennDOT appointed a project manager to supervise the planning and conduct of the project. Among the first steps in the planning process were (1) the establishment of a task force and (2) the retention of a traffic engineering consultant.

The task force was established to help identify potential problems and recommend solutions as well as to communicate with and generate support among the various constituents represented. Membership included municipal governments, the regional planning commission, chambers of commerce, mass transit and paratransit agencies, automobile and motor truck associations, the state police, and traffic-reporting services.

A traffic engineering consultant was retained to assist in the planning analysis. PennDOT management felt that traffic management was critical to the success of the project and therefore the traffic engineering function took the Figure C-3 lead in project planning. The consultant's work plan had five tasks: (1) establish and analyze the existing transportation situation, (2) develop reconstruction strategies, (3) evaluate the impact of recommended strategies on the local transportation network, (4) develop and design the traffic management plan, and (5) monitor the effectiveness of the plan.

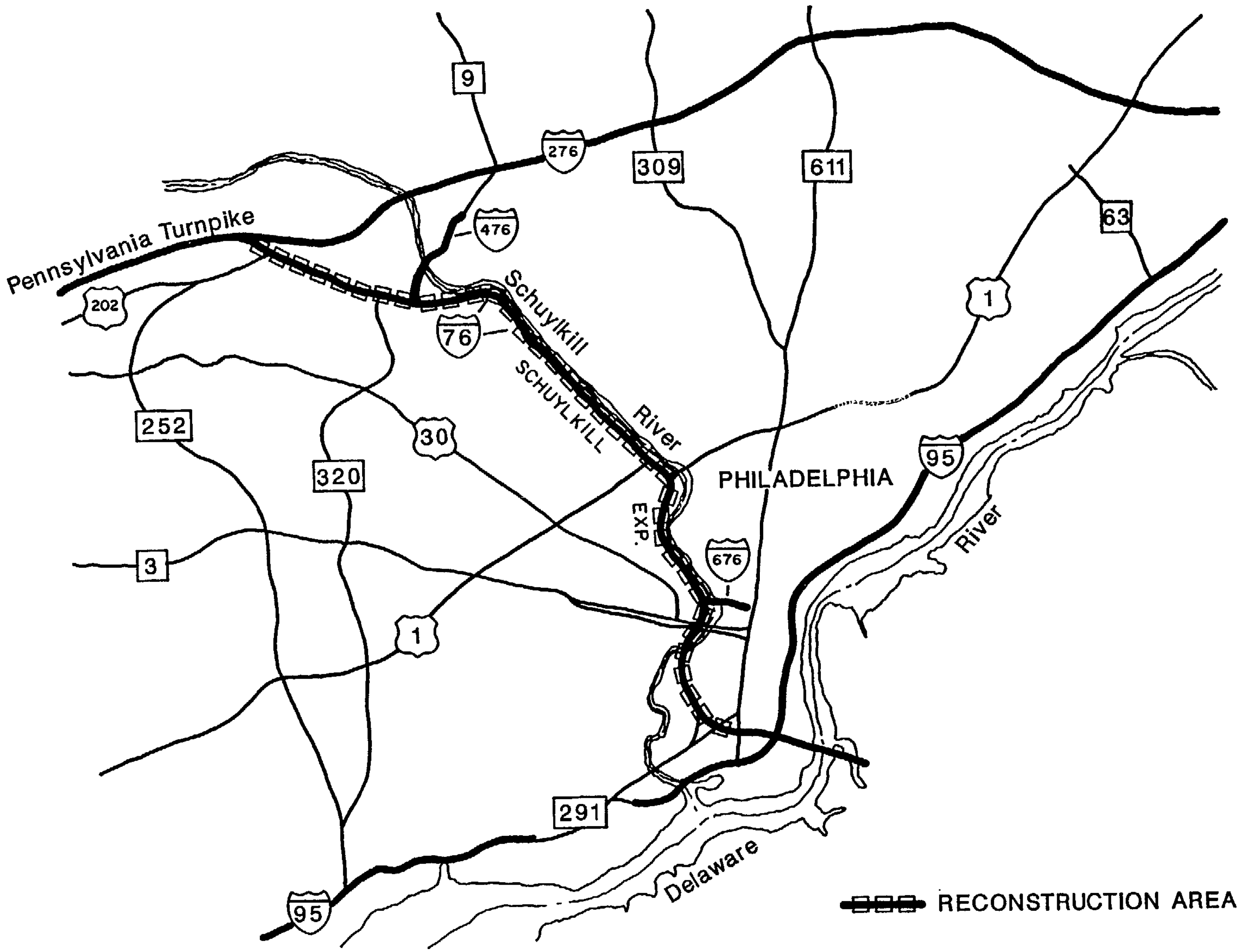

Figure C-3. Map of the Schuylkill Expressway Reconstruction Project Corridor in Philadelphia

The evaluation of the existing transportation situation included travel time studies on 15 parallel alternative routes to the Expressway, automatic and manual volume counts, vehicle classification counts, on-street parking studies, capacity analyses, a traffic signal inventory, and an origin-destination survey.

The origin-destination survey became the backbone of the planning analysis effort. Two factors contributed to the need for the survey. First, project planners believed the common perceptions about the usage of the Expressway--for example, that most trips were end to end--was not true. Project planners needed accurate information on travel patterns on the Expressway in order to develop an effective traffic management plan for the project and then to generate support for their plan. Second, existing origin-destination data were considered neither current nor specific enough for the planning effort. Therefore, an origin-destination survey was conducted on the Expressway in July 1982.

The origin-destination survey was conducted on two mornings (7:00 - 9:00 a.m.) in July 1982. Pre-addressed postage-paid post card questionnaires were distributed at the 40 entrance ramps on the Expressway. The questionnaires were coded according to the entrance ramp at which they were distributed. Motorists were asked to identify the origin and destination of their trip, the exit ramp they would use, the type of vehicle they were driving, and the occupancy of the vehicle. In addition, motorists were asked their preferred travel alternative should travel during reconstruction become inconvenient.

A total of 37,000 questionnaires were distributed of which 13,800 usable questionnaires were returned. The results were processed and used in several ways. Summary statistics were computed, primary interchange-to-interchange movements were identified, and major origin-destination patterns were determined. The average vehicle occupancy was 1.45 persons with 73.2 percent containing the driver only and an additional 17.5 percent containing only one passenger. The latter statistic suggested a potential for reducing travel demand by promoting ridesharing. The average length of the Expressway portion of the trips was 5.8 mi for eastbound motorists and 5.2 mi for westbound motorists. The primary interchange-to-interchange movements and the origin-destination patterns indicated that the Expressway served widely dispersed travel demands. Entrance ramp volumes were classified according to exiting ramp to define interchange-to-interchange movements. These data were used extensively in evaluating the impact of ramp closures on alternative routes and the effectiveness of strategies to mitigate adverse impacts.

The findings of the origin-destination survey coupled with the construction needs led to the development of basic traffic management goals and a construction schedule. The traffic management plan had three goals: (1) maintain at least one lane of traffic in each direction at all times, (2) encourage trucks, tourists, and other long-distance travelers to remain on the Expressway during construction, and (3) reopen all lanes of traffic between construction seasons.

It was decided to stage the project over three construction seasons (March to November) and to reconstruct two lanes of traffic at a time. In the four-lane segments, two-lane two-way traffic was maintained in one direction while work was performed in the other direction. The Expressway was prepared for two-way operation by upgrading the shoulders. Traffic operated on the shoulder and on the median lane with a safety lane in between. In six lane segments, four lanes of traffic were maintained during reconstruction; and in eight-lane segments, six lanes remained open.

The facts that the origin-destination pattern was dispersed and that average trip lengths were relatively short enabled reconstruction to be staged over the three years of the project in such a way that the impact on many affected communities could be confined to primarily one of the three years. The basic staging was planned as follows: in 1985, a 5-mi segment at the Turnpike terminus and a1.5-mi segment at the downtown end of the Expressway were reconstructed; in 1986, the 12-continuous-mi middle segment was reconstructed; and in 1987, a major downtown interchange was to be reconstructed. The work in 1985 was completed as scheduled. All but one contract let for the work in 1986 was completed. The one contract that was not completed in 1986 was terminated. The schedule has been revised such that some redesign work was performed in 1987 and the remaining portion of the middle segment and the interchange are scheduled for reconstruction in 1988 and 1989.

The reduction in the typical cross section from four to two lanes translates into a 50-60 percent reduction in capacity, which had to be accomplished by diverting short-distance, local drivers from the Expressway. A key to diverting traffic was the closure of most of the entrance ramps and some of the exit ramps within or leading to the construction zone. Ramps that were closed included: (1) entrance ramps in a construction zone where only one lane was open, (2) ramps with bridges that needed rehabilitation, (3) ramps that were blocked by a construction operation, and (4) ramps that would encourage more than the optimal number of drivers to use the Expressway if left open.

An analysis of the changes in traffic patterns that would result from the basic traffic management strategy was conducted in order to evaluate the impact on the alternative routes in the corridor. The analysis consisted of a manual reassignment of traffic to alternative routes. The process was tedious. For each ramp that was to be closed the traffic volumes on the ramp were identified from count data and the origins and destinations of those trips were determined from the origin-destination survey. Trips were manually assigned to the best available alternative route, which was identified using the data on capacities and travel times that were collected as part of the inventory of the existing street system. It was also recognized that the Expressway would not have sufficient capacity during reconstruction to accommodate all of the traffic entering the Expressway from the ends. Therefore, the origins and destinations of trips entering the Expressway at each end were identified. Trips for which good alternative routes existed were reassigned to those routes. The remaining trips--those with no good alternative routes--were kept on the Expressway.

The traffic reassignment analysis was performed manually and the results were plotted on maps. The analysts had good knowledge of local conditions and considered capacity bottlenecks in identifying the best alternative routes for diverted traffic. Strictly speaking, however, the traffic assignment was not capacity constrained.

The alternative routes and the public transportation system in the Schuylkill Expressway corridor were not considered capable of handling a 50 percent diversion of traffic. Therefore, a program of mitigation measures was undertaken to increase the capacity of alternative routes and to improve public transportation facilities and services. Maps of the results of the traffic reassignment analysis served as the basis for the identification of measures.

The traffic reassignment results were presented to the task force. Task force members representing affected communities and the local transit authority were asked to develop a “shopping list” of potential improvement to the alternative routes and to the transit system. The recommended solutions were analyzed by the traffic engineering consultant. A series of private meetings were held with the task force representatives of individual communities to finalize the list of improvements that would be funded in each affected community.

Traffic Management Strategy

The final impact mitigation program was budgeted at $12 million and included: (1) coordinating and retiming existing traffic signals and installing additional signals, (2) widening and constructing turning lanes on existing roadways, (3) accelerating maintenance and patching schedules on key alternative routes, (4) making transit improvements by expanding rail service farther west, (5) expanding programs to increase van/carpooling, and (6) assigning traffic control officers to key intersections and school bus stops.

In addition, an extensive public information program was undertaken. The program included traditional public relations tools: press conferences, news releases, interviews, media events, and public service announcements. In addition, several special activities were undertaken, including (1) developing and distributing a Visitor's Guide, which provided information and encouragement for truckers, tourists, and long-distance travelers to stay on the expressway, (2) developing a Commuter's Guide, which provided information and encouragement for local drivers to take alternative routes, and (3) providing a toll-free hotline to identify alternative routings, answer questions, take complaints, and distribute information.

Actual Travel Impacts

Travel impacts during reconstruction have not been documented. However, peak-period volume counts were taken on the main diversion routes during reconstruct/on, and the increases in traffic were similar to those that had been projected. Key intersections were monitored and changes in signal timing were made as deemed necessary.

Overall, the negative impacts were less severe than many had feared: "No massive traffic jams materialized, life went on in the City of Philadelphia, the tourists came as usual, and the region's drivers proved that given choices and information they could be quite resourceful and successfully cope with a major reconstruction project" (66).

US-IO, JOHN C. LODGE FREEWAY, DETROIT

The Lodge Freeway is a 30-to-35-year-old, six-lane freeway connecting downtown Detroit and its northwestern suburbs. AADTs prior to reconstruction were approximately 125,000 vpd at the maximum load point. The Michigan Department of Transportation (MDOT) undertook a two-year project to reconstruct a 8.4 mi section of the freeway between l-75 and Meyers Avenue. Figure C-4 illustrates the Lodge Freeway corridor. The project included (1) widening the outside shoulders, (2) constructing a safety shaped barrier wall on the outside edge of the shoulders, (3) extending and upgrading the drainage and storm sewer system, (4) removing and replacing the pavement, (5) improving several interchanges, (6) redecking one bridge and resurfacing another, (7) improving landscaping and erosion control, and (8) repairing pavement and joints on a 20-year-old section of the freeway north of the project limits. The two-year project was conducted during the 1986 and 1987 construction seasons (April through November).

Planning Process

Planning for the Lodge Freeway reconstruction project began in 1983. Several traffic management options for the project were considered:

1. Directional closures with two-way traffic in the open direction
2. Directional closures with one-way traffic in the open direction
3. Complete closure of the freeway in both directions

The question that had to be addressed was what would be the travel impacts of each alternative. MDOT contracted with the Southeast Michigan Council of Governments (SEMCOG), which maintains Detroit's regional transportation model, to identify the current users of the segment of freeway to be reconstructed and to estimate the changes in travel patterns and travel times associated with closing one or both directions of the Lodge.

SEMCOG used their regional transportation model, which was based upon FHWAs PLANPAC, to perform its analysis. They analyzed the base case (Lodge Freeway open in both directions) as well as the following alternatives:

1. Southbound direction open/Northbound direction closed
2. Northbound direction open/Southbound direction closed

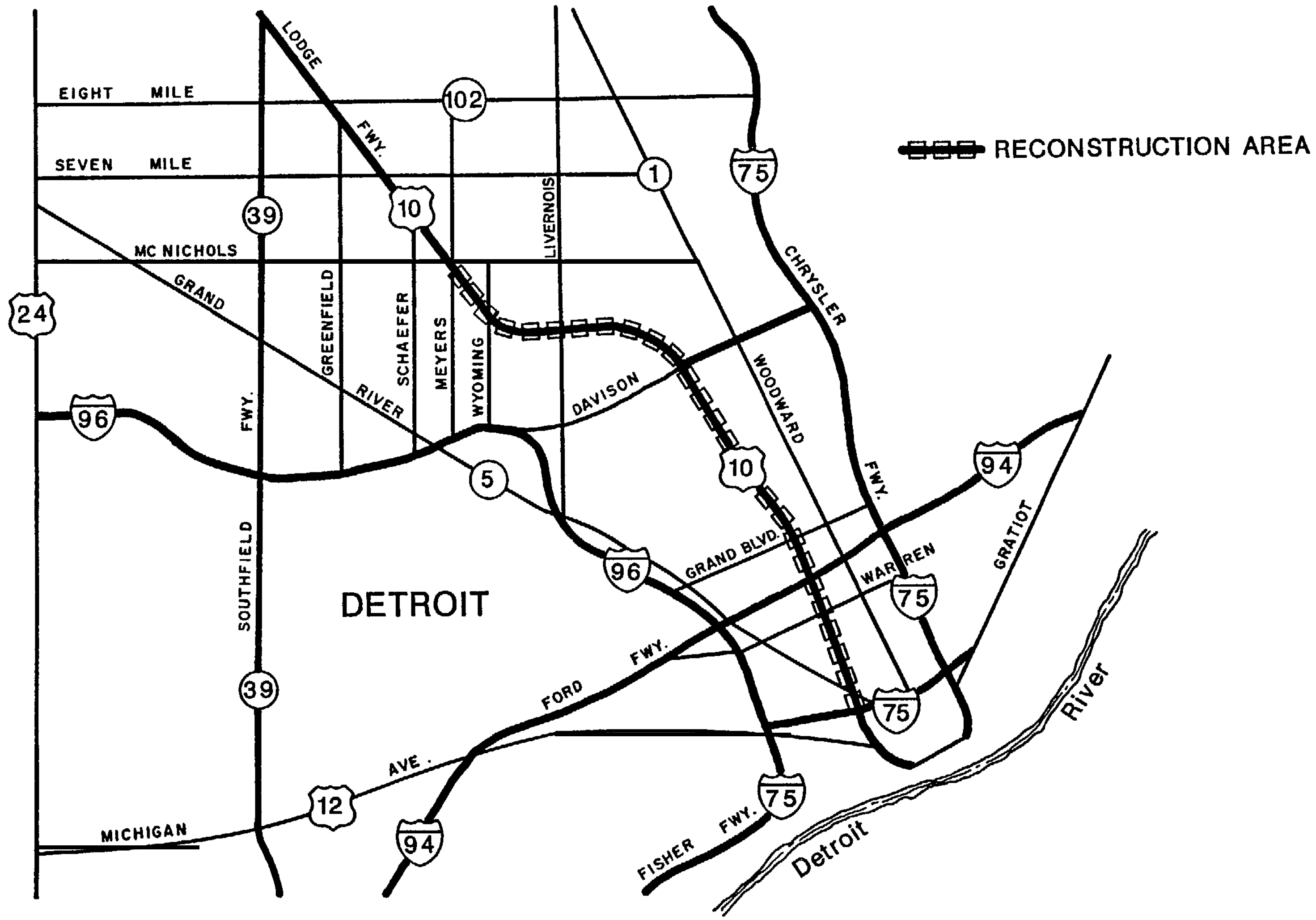

Figure C-4. Map of Lodge Freeway Reconstruction Project Corridor in Detroit

3. Lodge Freeway closed in both directions.

SEMCOG performed select link analysis to identify current users of the segment of freeway that would be closed. They developed trip tables for three links: one at the northern end of the segment to be reconstructed, one at the southern end, and one that carried the highest volumes near the middle of the segment. The objective was to capture a majority of the freeway trips on the trip tables.

SEMCOG did traffic assignment runs for the base case and for each alternative to predict the diversion patterns associated with each alternative. They made no adjustments or refinements to the regional network in running the assignments, except to remove the links corresponding to segments closed in each alternative. They assumed that the reconstruction would not change the trip generation and distribution results. SEMCOG used skimmed times from the traffic assignment runs to estimate the differences in travel times between the base case and each of the alternatives for trips which used one or more of selected links on either the Lodge or on primary alternative routes.

Table C-l summarizes the information that SEMCOG provided MDOT as the product of their analyses.

In addition to the analysis results obtained from SEMCOG, MDOT also obtained detailed information about traffic on the Lodge from the MDOTs Surveillance, Control, and Information system and performed travel time runs on the Lodge before reconstruction. MDOT did not use the absolute differences in traffic volumes and travel times that SEMCOG estimated using their traffic assignment models. Rather, MDOT applied the percentage in traffic volumes from SEMCOG to actual traffic volume counts to estimate changes in travel patterns. Similarly, MDOT applied the percentage difference in travel times estimated by SEMCOG to their data from actual travel time runs to estimate the changes in travel times. It was estimated that average travel times through the corridor would increase 20 percent during reconstruction.

The analyses of the travel patterns and traffic data suggested that the Lodge served primarily local traffic. A comparison of the O-D interchanges common to two selected links (one at the northern end of the segment to be reconstructed and the other at the middle of the segment) suggested that only IO-15 percent of the trips were through trips. This corresponded with the findings of an earlier City of Detroit study which had estimated that the average trip length on the affected segment of the Lodge was only 3.8 mi.

TABLE C-l. PLANNING INFORMATION FOR LODGE FREEWAY RECONSTRUCTION PROJECT DEVELOPED USING DETROIT'S REGIONAL TRANSPORTATION MODEL

Region-Wide Estimates for Each Alternative:

-vehicle miles traveled
-vehicle hours traveled

Screenline Comparisons for Each Alternative:

-sum of volumes across screenline
-sum of capacities crossing screenline
-ratio of screenline volume to base case volume
-ratio of screenline capacity to base case capacity

Select Link Reports for Each Alternative and Selected Link:

-sum of trips by origin zone
-sum of trips by destination zone
-ratio of sum of trips by origin zone to base case sum of trips
-ratio of sum of trips by destination zone to base case sum of trips
-map illustrating distribution of trips by origin zone
-map illustrating distribution of trips by destination zone

Plots of Difference in Volumes Due to Freeway Closure for Each Alternative

Project planners compared the capacity of alternative routes in the Lodge corridor with the volumes already on them to determine how much unused capacity was available for traffic diverted from the Lodge. Unused capacity was available on two major atterials, Woodward and Grand River Avenues, and on several alternative freeways, the Chrysler, Southfield and Jeffries. Planners estimated that these alternative routes could handle 78 percent of the traffic that would need to divert from the freeway if it were closed. MDOT believed that the remaining 22 percent of diverted traffic would be handled by city streets, increased ridesharing, and proposed increases in transit service (69).

The facts that the Lodge served primarily local traffic and that there was considerable unused capacity on alternative routes led MDOT to conclude that the Lodge could be closed during reconstruction without unreasonable disruptions in traffic flow in the corridor. The question that remained was which closure option to select. MDOT evaluated the construction as well as social and economic impacts of the options in addition to the travel impacts.

The option to close the freeway completely was considered the best option, for the following reasons:

1. Adequate capacity existed on alternative routes to accommodate most of the Lodge Freeway traffic

2. The detours to alternative routes would be in effect throughout the project (instead of changing for each direction in the other options), thereby minimizing confusion to motorists

3. The project could be completed in one construction season (instead of two seasons for the other options), thereby minimizing the time period over which motorists as well as neighborhoods and businesses would be impacted

Therefore, MDOT initially hoped to close the entire 8.4 mile freeway segment in both directions. But that idea was dropped after the City of Detroit and the downtown merchants raised strong opposition. The project was, therefore, planned for two-years duration--the northbound direction to be closed for seven months during 1985 and the southbound direction during 1986. Bids for the 1985 project came in much higher than expected due primarily to the massive amount of work to be performed in short time periods carrying heavy penalty clauses. The bids were, therefore, rejected and the project re-evaluated.

Traffic Management Strategy

The traffic management plan that was eventually implemented also involved staging the project over two construction seasons, but with a revised scheme. In 1986, work was performed on the outside ‘shoulders, barrier walls, drainage system, and storm sewer system. The work did not directly involve the travel lanes and, therefore, the freeway capacity reductions were minor. The traffic control plan allowed the outside lanes only to be closed during off-peak periods. All three lanes were kept open in the peak direction during peak periods. The travel lanes and the median shoulders were narrowed in order to provide a 6 ft right shoulder. Ramps could be closed, but no two consecutive on or off ramps at a time. During special events, all lanes and ramps were kept open. A 45 mph speed limit was posted through the construction zone as required by Michigan law.

In 1987, the removal and replacement of the pavement in both directions was performed. The traffic management plan for 1987 involved directional closures with one-way traffic maintained in the open direction. The northbound (outbound) lanes were closed from April through July 1987, and the southbound (inbound) lanes were closed from July through October 1987.

Numerous actions were taken to provide travel alternatives for Lodge Freeway users and, thereby, to mitigate the impacts of the project. An extensive public information program was implemented to advertise the alternatives. Operational and geometric improvements that were made to improve traffic flow on the alternative routes included (1) resurfacing one route, (2) improving signing and lighting, (3) improving connectors between a major traffic generator in the corridor and an alternative route, and (4) retiming and coordinating traffic signals.

MDOT also made several improvements to high-occupancy vehicle services including(l) increasing efforts to attract carpoolers and vanpoolers, (2) providing new express bus service, and (3) expanding service on several existing bus routes in the corridor. An extensive public information program was a vital part of the overall impact mitigation strategy. MDOT hired a media consultant to disseminate timely and correct information. MDOT also contracted with SEMCOG to coordinate the Public Information Program. SEMCOG, in turn, hired a Public Relations consultant and an advertising agency. The theme of the program was “Lodge-ability” which was defined as “the ability to get through, over and around the construction we’ve all been waiting for on the Lodge Freeway” (69). The public information program included (1) public meetings and presentations, (2) informational signing, (3) distribution of a variety of informational materials, (4) media briefings, (5) public service announcements, (6) paid advertising, (7) a telephone hotline, and (8) an ombudsman.

Actual Travel Impacts

A traffic monitoring program was implemented to count traffic at 48 locations in the Lodge Freeway corridor during the 1986 construction season, during both the northbound and southbound closures in 1987, and after the completion of the project in 1988. The 1988 data have not been collected as of the writing of this report. An in-house evaluation of the travel impacts will be performed after the 1988 data are collected. Preliminary results for the 1986 construction season suggested that traffic volumes on the Lodge decreased by 19 percent (69) It was not determined where the traffic went.

The City of Detroit Department of Transportation performed an independent evaluation of the, impacts of the reconstruction during 1987 on surface streets within the City of Detroit (70). Traffic volumes on surface streets in the Lodge Freeway corridor increased by approximately 25 percent in the direction of the closures. Average speeds in the direction of the closure decreased between 23 and 31 percent on the three suggested alternative routes analyzed and one surface street route. It was reported that traffic flowed smoothly on the alternative routes in spite of the volume increases due to signal coordination and special signing. In a research poll conducted between the 1986 and 1987 reconstruction phases, 85 percent of the motorists stated that they experienced little or no inconvenience.

Apparently, the primary response of motorists to the reconstruction was to use alternative routes. The express bus service that was implemented to reduce traffic congestion on the alternative routes was underutilized, in spite of an intensive media effort, and was discontinued in August 1987. The service was designed to accommodate 320 persons daily but was actually used by only approximately 35 persons per day. Similarly, ridesharing attracted little, if any, additional usage.

I-394, MINNEAPOLIS

I-394 is a new segment of Interstate highway being built by the Minnesota Department of Transportation (MnDOT) along the alignment of existing US 12 through the western suburbs of Minneapolis. Figure C-5 identifies the 11 -mi segment of US 12 from Trunk Highway (TH) 101 to downtown Minneapolis that is being reconstructed and upgraded to Interstate standards.

US 12 is the principal arterial highway linking the western suburbs with downtown Minneapolis. Existing US 12 was a four-lane divided highway with several at-grade intersections west of TH 100 and was a six-lane freeway east of TH 100. The AADT on US 12 in 1984 ranged from 49,000 vpd just east of I- 494 to 99,000 vpd at the maximum load point just west of Penn Avenue (71).

I-394 was added to the Interstate System in 1968. In 1975, the Minnesota Legislature restricted I-394 to a maximum of six through lanes. It was determined early in the planning process that six conventional lanes would not be able to accommodate forecasted traffic volumes. Therefore, I-394 was designed with four conventional lanes and two HOV lanes as part of an overall transportation system management (TSM) plan for the corridor (71)

The reconstruction project began in 1985 and is scheduled for completion in 1992. The project includes the reconstruction of US 12 to Interstate standards between TH 101 and I-94, and the construction of the Third Avenue Distributor and parking garages east of I-94. The Third Avenue Distributor provides bus roadways between I-394 and downtown streets, HOV bypass lanes around ramp meters at entrance ramps, and direct connections between I-394 and the three parking garages that are being built over I-394.

I-394 will have two typical cross sections. In the most heavily trafficked eastern portion of the corridor (between TH 100 and I-94), the cross-section will consist of three two-lane roadways. The center two-lane roadway will be reversible to serve HOVs only in the peak flow direction. To the west of TH 100, the cross section will consist of two three-lane roadways with the left lanes restricted to HOVs in both directions during both peak periods.

Project Planning

The HOV-lane concept was adopted in 1981 and the final Environmental Impact Statement was completed in 1982. A study process was undertaken to develop a

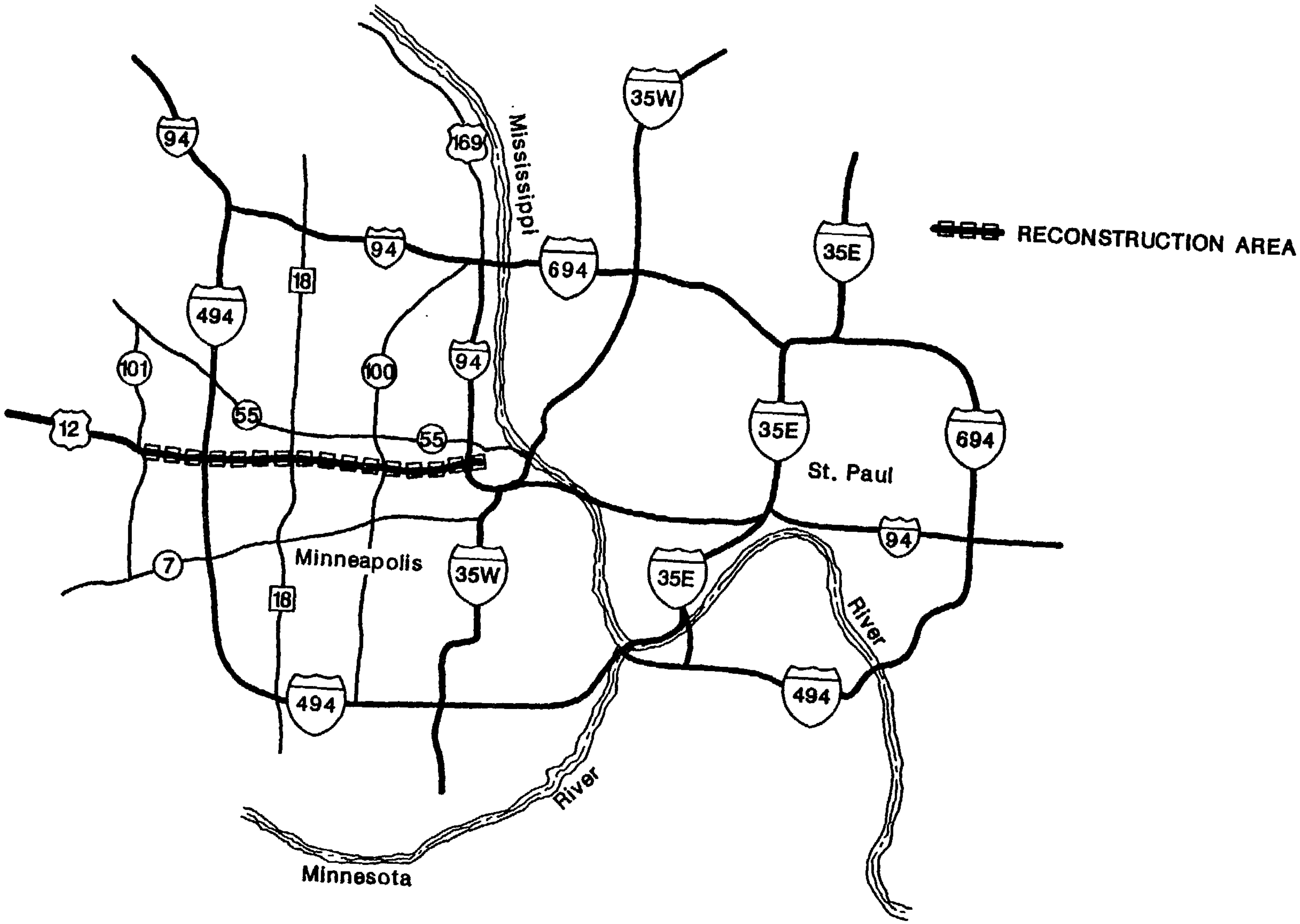

Figure C-5. Map of the I-394 Reconstruction Project Corridor in Minneapolis comprehensive TSM Plan for the I-394 corridor. The traffic management plan for the construction period was developed as part of the overall TSM Plan.

The TSM Plan was developed with the assistance of three groups: a Policy Committee, a Project Management Team, and a Marketing Committee. All three committees were headed by MnDOT personnel and included representatives from local government agencies and transit commissions. The Policy Committee was responsible for major policy decisions and the overall direction of the project. The Project Management Team was responsible for routine decisions and the daily direction of the Plan; the Team is headed by a Corridor Manager. The Marketing Committee assisted in the development and implementation of a Marketing and Public Information Plan for the corridor. Much of the data collection and analysis for the study process was performed by a consultant.

The fundamental design objective for I-394 was to maximize the people carrying capacity of the corridor. The I-394 TSM Plan is a coordinated package of components to promote HOV use. The components include ramp meter bypass ramps for HOVs and buses, local-to-express bus transfer centers, park and ride lots, timed transfer bus scheduling, rideshare programs, and parking garages at the downtown terminus.

The study process for the development of the I-394 TSM Plan included an inventory of existing conditions and traffic forecasts for the year 2000.

The inventory of existing conditions documented (1) the demographic characteristics of the area; (2) traffic volumes, origins and destinations; (3) carpool/vanpool volumes, occupancy and distribution; (4) transit ridership and distribution; and (5) travel times, speeds, and delays. Demographic characteristics were based on 1980 census data. Traffic volume and vehicle occupancy counts were taken in 1984. Existing origin-destination data were used. Transit ridership and distribution data were compiled as part of a series of surveys of bus ridership, market potential, and carpooling in 1982 through 1984. Travel time, speed, and delay data were collected in 1984.

Traffic forecasts were prepared by MnDOT in 1980 with the assistance of the Metropolitan Council using the Council's Regional Travel Models of the regional highway network and a Quick Transit Sketch Planning modal choice model. Manual adjustments were made to these forecasts in 1984 to account for (1) highway design changes, (2) changes in land use, employment forecasts and trip generations at specific locations, (3) new traffic count data at specific locations, and (4) the tendency for the Quick Transit Sketch Planning model to overestimate bus trips and underestimate Carpool trips.

The inventory of existing conditions made it clear that there would not be adequate capacity on parallel alternative routes (principally TH 55 and TH 7) to accommodate significant amounts of traffic diverted from US 12 during construction. Therefore, the following policy statement, established by the Policy Committee, governed the planning for the construction project (71):

> <u>REASONABLE TRAFFIC FLOW WILL BE MAINTAINED ALONG TH 12 DURING CONSTRUCTION</u>. Traffic must continue to operate on TH 12 during construction of I-394 because alternate routes do not have the capacity to accommodate much additional traffic. The construction period also offers an excellent opportunity to introduce the HOV express lane concept at a time when people may be more willing to accept alternatives due to the negative impacts of construction on travel time.

The Policy Committee also established the following subpolicies to govern traffic operations during the construction period (71):

1. "At least two through lanes of mixed traffic in each direction during peak periods will be maintained during construction."
2. "A single reversible lane or diamond lanes will be provided, where cost-effective, for HOVs during peak periods before and during construction. These HOV lanes will be in addition to four through lanes for mixed traffic."
3. "Reasonable access will be provided to all existing land uses during construction."
4. "Programs encouraging greater HOV use such as increased transit service, low parking prices, parking preferences for HOVs, and rideshare programs will be implemented before and during construction."

The goal of the traffic management plan was to maintain the same level of performance for mixed traffic during construction as before. One key to attaining that goal was the decision to maintain two through lanes of mixed traffic in each direction. The construction staging to accomplish this was complex. The project was divided into eight major segments that will be completed over an eight-year period. Temporary detours and bypasses are required at several locations to maintain two lanes on US 12 as well as to minimize the disruption to cross route traffic.

However, even though two lanes were maintained in each direction, there were capacity reductions due to narrow lanes and the use of detours with additional signalized intersections. MnDOT estimated that the most severe bottleneck had a 25 percent reduction in capacity. Therefore, in order to maintain the same level of performance for through traffic, it would be necessary to divert up to 25 percent of traffic.

Interim HOV Express Lanes. The key component of the traffic management strategy for the project was the construction of an interim HOV express lane in the median of the existing highway. The interim HOV lane, termed the “sane lane” for publicity purposes, would serve several objectives. Not only would it provide additional route capacity, but also it would serve as a training facility to introduce and acclimate motorists to the use of the permanent HOV lanes. In addition, it was seen as a way of providing continuity for motorists between completed, under-construction, and as-yet untouched segments of the project (72).

The I-394 Policy Committee stated that an HOV lane should be provided, where cost effective, in addition to the four through lanes for mixed traffic. Therefore, a cost-benefit analysis was performed to determine whether the construction of the interim HOV lane was justified.

The interim HOV lane was divided into six segments that could be implemented in stages corresponding to the staging of the overall project. The design of the interim lane in each segment varied. Certain segments would have reversible lanes in the existing median. Other segments would make an existing travel lane a diamond lane. Two alternative designs were considered for the segment east of TH 100.

Standard procedures were used to perform the cost-benefit analysis (73). The analysis was performed for each segment individually as well as for the facility as a whole. Costs were estimated for the construction, maintenance, and operation of the HOV lane. Benefits were measured in terms of vehicle operating costs and travel time costs. Benefits were computed as the difference between operating and time costs with and without the interim HOV lane during construction. Since it was difficult to predict with confidence the usage of the HOV lanes, benefits were estimated for two different levels of usage. A low estimate of usage was based upon existing conditions, i.e., no growth in existing traffic volumes or HOV use. A high estimate of usage was based upon usage at 1989 volume levels, assuming straight-line growth between existing and forecasted volumes and mode split.

A cost-benefit ratio was estimated for each segment individually and for all segments combined. The cost-benefit ratios for the individual segments suggested that each was justified on a stand-alone basis except for the Plymouth Road segment and one of the alternatives for the segment east of TH 100. The cost-benefit ratio for all segments west of TH 100 combined was 1.17, for the low estimate of usage, and 1.55, for the high estimate of usage.

The cost-benefit analysis was the basis of the decision to construct the four segments of the interim HOV lane west of TH 100 to coincide with the construction schedule. The decision was made to construct the Plymouth Road segment even though it was not justified on a stand-alone basis because it was important from a continuity standpoint. The cost-benefit analysis was also the basis for selecting the design alternative for the segment east of TH 100.

FHWA authorized the expenditure of Interstate funds for the construction the interim facility. Two discontinuous segments of interim HOV lane were constructed in 1985 and opened in November 1985. Additional segments are constructed as new phases of construction get underway.

Several programs were implemented to encourage HOV use. Improvements in bus service in the corridor were implemented in December 1985 toward the ultimate transition to a timed-transfer system. Ridesharing programs were expanded to encourage people to use the interim HOV lane. An aggressive marketing and public information program was implemented. A temporary HOV parking lot was constructed to provide free parking for carpoolers.

The marketing and public information program was implemented primarily to encourage ridesharing and the use of the HOV lanes both during and after construction. The program included media relations (press kit, releases, conferences, and tour), meetings with special target groups (legislators, police, businessmen, and citizens groups), a telephone hotline, special advertising (billboards, radio spots, and newspaper ads), and direct mailings (brochure, semi-annual newsletter, and bus schedules).

In addition to the marketing of the use of the HOV lanes, motorists were also encouraged to consider two other options during construction: (1) to use alternative routes, and (2) to drive at alternative off-peak times.

Alternative Routes. Figure C-5 illustrates two parallel alternative routes to US 12: TH 55 and TH 7. TH 55 is the best alternative. Major improvements were made to TH 55 before construction began on US 12. The improvements, which included signalization, widening, and resurfacing, were not funded as part of the l-394 project. Many of the improvements were needed anyway, but MnDOT wanted to complete the improvements before the l-394 project began in order to maximize the capacity available on TH 55 during the l-394 project. TH 7 is a heavily traveled city street. No major improvements were made to this route because of limited right-of-way.

Actual Travel Impacts

An evaluation plan was part of the l-394 TSM Plan. The evaluation plan included traffic monitoring during construction. Traffic volumes, vehicle occupancy, and travel times have been monitored throughout construction.

The response of motorists has been similar to that for other projects. On the first day of construction in 1987, traffic volumes on US 12 were only about 50 percent of normal volumes. Traffic volumes on TH 55, the best alternative route, increased and some delays occurred, but there were no serious problems. During the first week of construction, motorists gravitated back to US 12 and during-construction volumes leveled off at 85 to 90 percent of pre-construction volumes.

An emphasis of the monitoring program during construction is the effectiveness of the interim HOV express lane. FHWA sponsored an evaluation of the effectiveness of the HOV lane based upon the first year of operation. The evaluation concludes that "The l-394 'Sane Lane' has been a recognized success during its first year of operation from many perspectives: operation, increases in HOV use, public acceptance of the HOV concept, and benefit-cost" (74). At the end of the first year of operation, the HOV lane was carrying 1600 people in 540 vehicles during the morning peak hour, compared with 1000 people in 890 vehicles on each of the mixed traffic lanes. Both Carpool and bus ridership increased. Travel times for both carpoolers and bus riders decreased. Overall auto occupancy rates on US 12 increased. The benefit-cost ratio for the interim HOV lane during the construction period was estimated between 1 .I3 and 1.27.

APPENDIX D

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