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16. Abstract

This report summarizes the corridor traffic management experiences at completed and ongoing construction projects nationwide. A corridor traffic management plan for a major freeway construction project has three components: (1) the traffic control plan for the construction zone, (2) impact mitigation actions on alternative routes and modes in the corridor, and (3) the public information program. The various strategies and techniques that have been used as part of each component are identified. Data regarding the costs and effectiveness are presented where available. This document will assist highway agencies when developing corridor traffic management plans for major construction projects in the future.

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SYNTHESIS OF TRAFFIC MANAGEMENT TECHNIQUES FOR MAJOR URBAN FREEWAY RECONSTRUCTION

by

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May 1989

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
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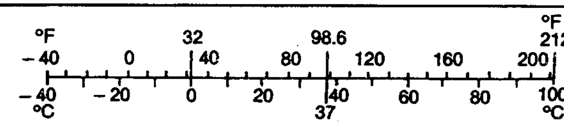
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Much of the information contained in this synthesis was obtained through conversations with officials involved with each of the construction projects reviewed. Although too numerous to mention, the authors wish to express their appreciation to these individuals for their assistance during the data collection phase of this effort.

Mr. Ray Derr, (SDHPT) served as the Technical Coordinator for the study. His efforts as Coordinator of this study are also gratefully acknowledged.

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

SUMMARY

This report synthesizes the traffic management experiences from 12 completed or ongoing urban freeway construction projects nationwide. The traffic impacts of a major construction project may extend beyond the freeway being reconstructed to alternative routes and modes, making it necessary to develop a corridor-wide traffic management plan for the construction project. A corridor-wide plan consists of three components: (1) a traffic control plan for the freeway being reconstructed, (2) transportation system management (TSM) type of improvements to accommodate diverted traffic to alternative routes and modes in the corridor, and (3) a public information program for nearby residents, businesses, and motorists using the facility.

Three basic traffic control plans have been used during construction: (1) narrow lanes and/or reduced or eliminated shoulders, (2) freeway lane closures, and (3) total freeway closures of one or both directions. Regardless of the traffic control plan used, it is desirable to maximize the capacity of the freeway construction zone as much as possible. Several techniques for maximizing the capacity of the freeway construction zone have been employed, including portable concrete barriers, paddle screens, ramp closures or restrictions, shoulder conversions to temporary travel lanes, reversible lanes, and incident management techniques. Experiences to date indicate that each of these techniques can provide benefits within the construction zone.

Experiences at the projects reviewed indicate that the most common change in travel patterns during freeway construction is diversion to alternative routes. Consequently, the improvements on alternative routes in the corridor have been important for maintaining acceptable levels of service on the routes. Improvements on alternative routes fall into three basic categories: (1) traffic signal improvements, (2) other intersection improvements, and (3) other roadway improvements. Within each category, several actions are possible, ranging from those that are temporary and relatively inexpensive to those that are more permanent and capital-intensive. The effectiveness of each action depends upon both existing site-specific conditions and the amount of diversion that is anticipated.

Diversion of construction zone traffic to public transit or other high occupancy vehicle (HOV) use has been heavily emphasized at some of the projects. However, experiences suggest that construction projects are unlikely to change motorists' long-held mode choice patterns. Even with costly improvements and promotions, it has been difficult to increase in transit ridership significantly during construction. Expanding existing transit or HOV services has been more successful than initiating totally new services. However, it appears that, just as for HOV programs under normal corridor conditions, a substantial travel time advantage for HOVs may be needed before significant numbers of motorists divert to HOV modes during construction.

An important lesson learned from the projects reviewed is that it is difficult to predict how motorists will change their travel patterns in response to a construction project and, consequently, that there should be room for considerable flexibility in the implementation

of a corridor traffic management plan. Certain TSM techniques offer flexibility and may be implemented with little risk. For example, signal timing changes, turn prohibitions, and parking restrictions on alternative routes are relatively inexpensive and can be modified at low cost in response to changing traffic conditions. However, certain capital-intensive improvements, such as intersection channelization, or capital improvements to public transit systems are more permanent. A strategy used at several projects has been to accelerate the implementation of improvements already scheduled for alternative routes so that they are in place before construction begins. In a similar fashion, implementation of some improvements can be put on hold until conditions during construction are evaluated and the need for the actions verified. A final alternative is to implement actions on a temporary basis and subsequently to reduce or eliminate those actions that are found to be unnecessary. Incorporating as much flexibility as possible facilitates modifications to the traffic management plan during construction, and thereby enables the plan to be more responsive to changes in traffic conditions.

IMPLEMENTATION STATEMENT

Each construction project is unique. Traffic management techniques that are effective at one project may not work at another. Therefore, caution must be exercised in applying the experiences from the projects reviewed in this report. Throughout the report, both the similarities between projects and the reasons for differences have been highlighted. The data presented indicates the order-of-magnitude of the costs and effectiveness of traffic management techniques that have been employed nationwide. Certain techniques, particularly the low-cost improvements on alternative routes, have been consistently cost-effective. In contrast, the cost-effectiveness of other improvements, particularly improvements to alternative modes, has varied depending on location. Continued documentation of experiences during major urban freeway construction is needed in order to develop a clearer understanding of the interactions between the components of a corridor traffic management plan and the site-specific characteristics that influence the cost effectiveness of alternative traffic management techniques. Until more data are gathered, this document may serve as an aid to engineers and planners struggling with the difficult task of traffic management for major freeway construction projects.

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1. INTRODUCTION

The United States is in the midst of an era of major urban freeway construction. Many major projects have been completed or are underway; many additional projects are being planned. This report compiles the experiences from a sample of completed or ongoing projects and provides an evaluation of the lessons learned from those experiences. The goal is to capture in one document the collective knowledge gained from past experiences for the benefit of highway agency personnel responsible for planning and implementing upcoming projects.

Background

A wide variety of traffic management techniques have been implemented and a wide range of travel impacts have been observed at urban freeway construction projects throughout the United States.This report provides a synthesis of the experiences from the following projects (in chronological order):

1. I-94, Edens Expressway, Chicago (1978-1980)
2. I-376, Penn-Lincoln Parkway East, Pittsburgh (1981-1982)
3. I-10, Katy Freeway, Houston (1983-1984)
4. I-81, Syracuse (1984)
5. I-93, Southeast Expressway, Boston (1984-1985)
6. I-5, Ship Canal Bridge, Seattle (1984-1985)
7. I-76, Schuylkill Expressway, Philadelphia (1985-1989)
8. I-394, Minneapolis (1985-1992)
9. US-10, Lodge Freeway, Detroit (1986-1987)
10. I-91, Hartford (1986-1990)
11. I-94, Milwaukee (1987-1989)
12. I-95, Miami (1987-1991)

Fortunately, for many of the projects documentation is available on the planning process followed, the traffic management strategies implemented, and travel impacts experienced (1-3). Each project was different--with a unique set of conditions and constraints that led to the diversity of traffic management techniques and actual travel impacts. The available documentation of individual projects is extremely valuable. This report is a compilation and evaluation of the body of experience as a whole. The value of such a synthesis is that it (1) reveals common elements that contribute to the success of projects, and (2) provides considerable insight into the characteristics of the project, the freeway, and the urban area that influence the effectiveness of the various strategies.

Objectives of the Report

The three objectives of this report are to:

1. Compile the experiences with traffic management from a sample of major urban freeway construction projects throughout the United States,

2. Summarize available data on the effectiveness of the various traffic management strategies that have been employed, and

3. Evaluate the potential applicability of the various strategies in Texas.

Scope of the Report

Since this report is for, and based upon research sponsored by, the Texas State Department of Highways and Public Transportation (SDHPT), the focus is on the lessons that might be learned from major urban freeway projects outside of Texas. Reference is made to construction projects in Texas for comparative purposes.

The scope of the research was limited to information that could be obtained from published documentation, in-person or telephone interviews with project personnel, and materials from project files provided by those personnel. There was no primary data collection at any of the projects.

Organization of the Report

The report has six chapters. Chapter 2 describes corridor traffic management considerations for urban freeway construction projects. Chapters 3, 4, and 5 are devoted to the three components of a corridor traffic management plan: the construction zone traffic control plan, improvements to alternative routes and modes in the corridor, and the public information program. Chapter 6 presents a summary and the conclusions reached regarding the effectiveness of the various corridor traffic management strategies and their applicability in Texas.

2. CORRIDOR-WIDE TRAFFIC MANAGEMENT FOR CONSTRUCTION PROJECTS

This section describes a corridor-wide approach for managing traffic during major freeway construction projects. A corridor-wide approach recognizes that the impacts of freeway construction often extend beyond the freeway to alternative routes and transportation modes. Such an approach, implemented through a corridor traffic management plan, promotes the ultimate goal of minimizing the total costs of a reconstruction project and provides the opportunity to consider a wider range of options for accommodating traffic during construction.

Rationale for a Corridor-Wide Approach

Many of the highway construction projects conducted during the years ahead will be on heavily traveled urban freeways. The problem of reconstructing an urban freeway, while accommodating the large traffic volumes that use it, is a formidable one. In an attempt to minimize resulting delays to motorists, the basic policy adopted by the SDHPT for handling traffic during major urban freeway construction projects has been to maintain the same number of freeway lanes during peak periods as were available before construction began. A corridor-wide evaluation of this policy would consider (1) that even minor reductions in highway capacity (resulting from narrowing lane and/or shoulder widths) on a heavily traveled freeway could cause significant disruptions in traffic flow, (2) that the disruptions in traffic flow could extend beyond the freeway to alternative routes and modes in the corridor, and (3) that, as a result, the traffic management plan for the construction project may need to include improvements on alternative routes and modes in the corridor in addition to a sound traffic control plan for the construction zone.

The ultimate goal in planning a construction project on a heavily traveled urban freeway is to satisfy two conflicting objectives:

1. Maximizing the safety and efficiency of the construction activity, and

2. Minimizing the adverse impacts on motorists, adjoining property owners, and affected communities.

In recent years it has become necessary to sacrifice some of the efficiency of the construction activity in order to reduce the adverse impacts on motorists (e.g., delays that necessitate changes in departure time, route or mode of travel), adjoining property owners (e.g., noise and dust), and affected communities (e.g., loss of business or increased traffic volumes on local roadways).

Roadway space must be shared by the required construction activities and the motorists. The Department's goal should be to allocate roadway space so as to minimize the total cost of the project. The total cost of the project consists of four main components: (1) the construction cost, (2) the cost of traffic control and traffic management, (3) the additional delay, vehicle operating, and accident costs to motorists and (4) the cost of damages to adjoining property owners and affected communities. Typically, the cost and/or duration of the construction project could be reduced by allocating adequate roadway space to construction activities. However, reducing highway capacity increases motorist costs by increasing congestion levels and, therefore, reducing average speeds which increases travel time. The cost of traffic control and traffic management increases as the magnitude of the capacity reduction increases. Unfortunately, at present there is not sufficient data to quantify these tradeoffs. A principal objective of this report is to compile available data on the cost-effectiveness of various traffic control and traffic management options. Another study (SDHPT Study No. 2-8-87/9-1108) is assessing the motorist cost impacts of reconstruction.

A corridor-wide approach expands the range of traffic control and management options that may be considered. The experiences compiled in this report suggest that a variety of options are available for accommodating traffic during construction. Options include narrowing lane and/or shoulder widths, lane closures, and total freeway closures. Importantly, both lane closures and total freeway closures have proven feasible when supplemented by improvements to alternative routes and modes accompanied by extensive public information programs. The construction projects on I-376 in Pittsburgh and I-76 in Philadelphia are examples of projects in which a corridor-wide approach was taken during the planning process and for which corridor traffic management plans were developed and successfully implemented. In both Pittsburgh and Philadelphia, available right-of-way was so restricted that it was necessary to reduce freeway capacity significantly in order to provide adequate work space and to complete the construction in an acceptable period of time. Little, if any, unused capacity was believed to be available on alternative routes in the freeway corridors, and therefore a package of transportation systems management (TSM) improvements was implemented to increase the capacity of alternative routes and modes. Although motorists were delayed and inconvenienced, the public response to the projects was generally positive. Additional information on these and other projects is presented in subsequent chapters of this report.

Corridor Traffic Management Plan

A corridor traffic management plan differs from a typical traffic control plan in that its scope extends beyond the right-of-way of the freeway under construction to alternative routes and modes in the corridor. The traffic management issues that need to be resolved in a corridor-wide plan are (1) the proportion of normal freeway capacity that should be maintained through the construction zone, and (2) the corresponding volume of traffic that will divert to other routes and transportation modes and consequently must be accommodated. Figure 2.1 illustrates the tradeoffs. The volume of traffic that must either change departure times or divert to an alternative route or mode increases as the percentage reduction in freeway capacity increases. As a result, the efforts required to reduce the adverse impacts on alternative routes and modes increase as both the percentage reduction in freeway capacity and the volume of diverted traffic increase.

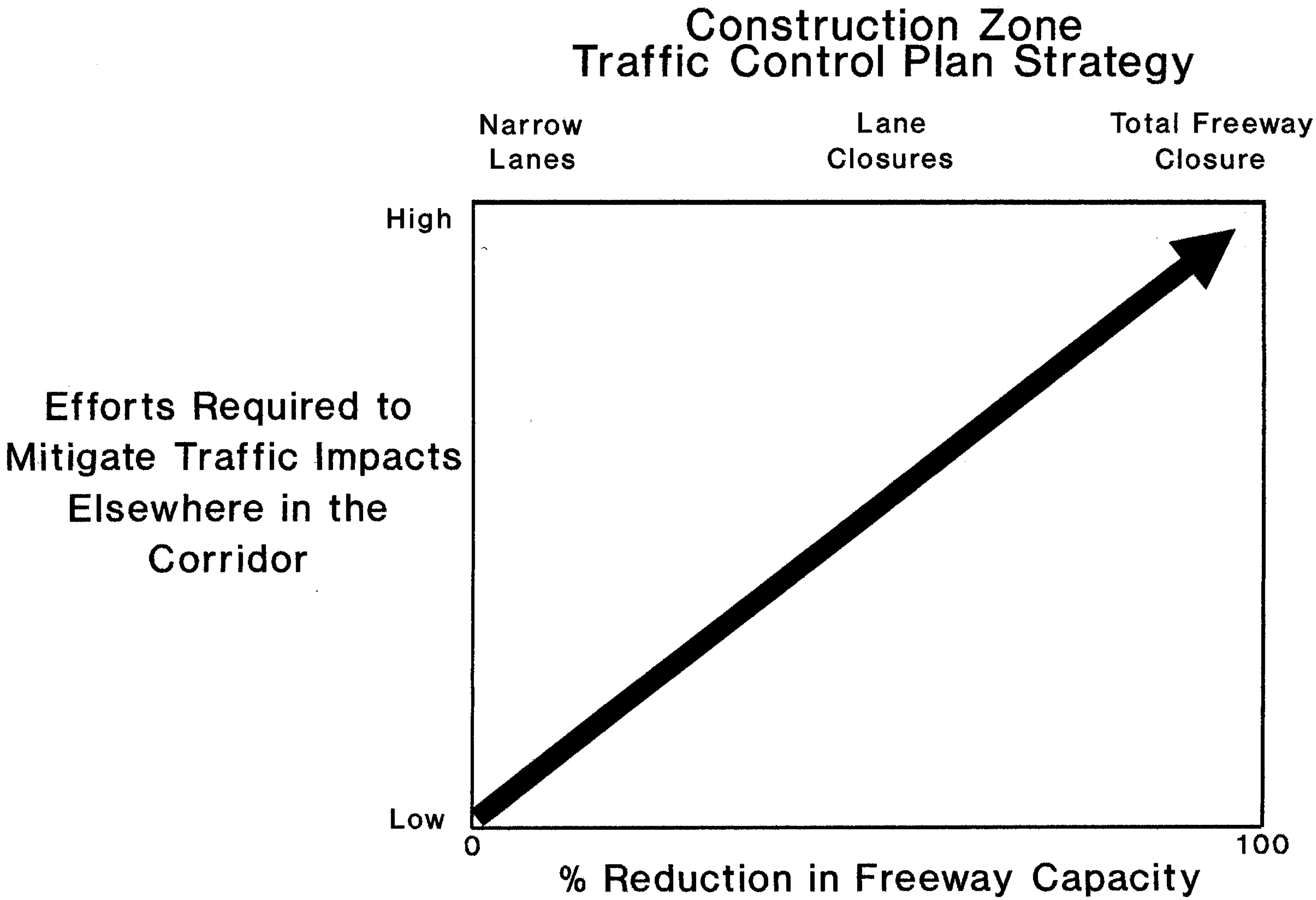


Figure 2.1. Tradeoffs in Corridor-Wide Planning for Major Urban Freeway Construction Projects.

The three components of a corridor traffic management plan are:

1. The construction zone traffic control plan,

2. Improvements to alternative routes and modes in the corridor, and

3. A public information program.

The traffic control plan details how traffic will be accommodated in the construction zone. The three basic categories of traffic control plans are: (1) narrowing lane and/or shoulder widths, (2) freeway lane closures, and (3) total freeway closures. Chapter 3 discusses the major considerations in selecting a strategy for a particular project, summarizes experiences with each strategy, and describes techniques that have been used to maximize the capacity of the construction zone.

Improvements on alternative routes and modes are TSM-type actions to increase capacity and improve the level of service on alternative routes and modes. Chapter 4 provides a catalog of strategies that have been employed and summarizes data on their cost and effectiveness.

The public information program is an essential component of a successful corridor traffic management plan. The objective of the program is to provide up-to-date and accurate information about traveling conditions in the construction zone and on alternative routes and modes in order to allow motorists to make wise route, mode, and departure time decisions. Examples of public information tools that have been used throughout the United States are described in Chapter 5.

3. THE CONSTRUCTION ZONE TRAFFIC CONTROL PLAN

One of the most important decisions that must be made when developing a corridor traffic management plan is how to divide the roadway space within the construction zone between the contractor who is working on the road and the motorists who wish to use it. In general, traffic control plans within construction zones can be categorized as to how severely they restrict the normal capacity of the roadway being constructed. The three basic options that are available are:

1. Narrow lanes and/or shoulders--reducing lane widths and/or reducing or eliminating shoulders (but maintaining the same number of travel lanes as existed before construction began).

2. Lane closures--the closure of some, but not all, lanes in one or both directions of travel on the highway being constructed. Traffic flow through the construction zone is still possible, but on fewer lanes than existed before construction.

3. Total freeway closures--the closure of all lanes for one or both directions of the highway being constructed. No traffic is allowed to flow through the construction zone in the affected direction. All motorists must all use alternative routes or modes to reach their destination.

This chapter discusses the major considerations involved in selecting which of these options is most appropriate for a particular project, summarizes experiences with each option at past projects, and describes techniques that have been used in conjunction with these options to improve the capacity of the construction zone.

Considerations in Selecting a Traffic Control Plan

From the point of view of developing a corridor traffic management plan for a construction project, many factors must be considered when selecting a traffic control plan for the construction zone itself. Some of the major factors include:

1. The existing cross section and amount of available right-of-way,

2. The type of work that must be performed,

3. The time constraints for performing the work,

4. The volume of traffic that normally uses the freeway, and

5. The availability of unused capacity on alternative routes and modes in the corridor (or the ability to increase their capacity),

6. The volume of traffic that might divert to these alternative routes and modes, and

7. The goals and policies of the highway agency with respect to acceptable levels of travel impacts.

The existing cross section of the construction zone and the available right-of-way define the supply of space that must be divided to accommodate the needs of both the work activity and traffic. The amount of work space needed is a function of the type of work that must be performed and the time frame within which it must be completed. The amount of space needed for traffic is largely a function of the volume of traffic that normally uses the freeway as well as the amount expected to use it during construction. A corridor-wide traffic management approach recognizes that some motorists may divert from the freeway to alternative routes and modes in the corridor. If considerable unused capacity is available on alternative routes (or can be created through improvements in capacity along the routes), then lane closures or total freeway closures can be considered as possible options for the freeway being constructed.

Whereas traffic volumes in rural areas may be low enough that travel lanes may be closed without causing significant delays and congestion to motorists, traffic volumes in urban areas are generally so high that almost any reduction in freeway capacity will adversely affect traffic operations. As a result, conventional wisdom is to maintain as much capacity on the freeway as possible without excessively limiting construction activities. In some cases, such as for I-10 (Katy Freeway) in Houston, it was possible to "squeeze" adequate work space out of the available right-of-way while maintaining the same number of travel lanes, albeit with narrower lanes and without normal shoulders. In other cases, such as Pittsburgh and Philadelphia, the existing cross section and right-of-way was so restricted that long-term lane closures (those remaining several months) were the only feasible options. In yet other cases, including Detroit, there has been available capacity on alternative routes and travel modes so that long-term lane closures or total freeway closures could be used to reduce construction time without severely inconveniencing motorists.

Unfortunately, there is as yet no objective basis for quantifying the trade-off between limiting construction activities and inconveniencing motorists. Ideally, one would like to divide the roadway space between the construction activity and the motorists so as to minimize the total cost of the project. Considerable savings could be achieved by evaluating the costs of different distributions of roadway space to the work activity and to the motorists. Throughout the country, long-term lane closures and total freeway closures have been implemented as part of a coordinated corridor traffic management plan without causing unacceptable inconvenience to motorists. Particularly where substantial unused capacity exists in the corridor or where capacity improvements can be made to alternative routes and modes, project planners should consider the possibility that long-term lane closures or a total freeway closure could be the lowest total cost option. The corridor-wide approach described in this report provides a framework within which such an assessment could be made.

Experiences with the Basic Traffic Control Plans

Table 3.1 summarizes the basic traffic control plan used at the 12 construction projects reviewed in this report. The implementation of these plans at each project are described briefly in the following paragraphs. Appendix A contains more detailed descriptions of each project. The descriptions include maps of the affected corridor and schematics of the basic traffic control plan used.

Narrow Lanes and/or Shoulders

The projects in Boston (I-93), Minneapolis (I-394), Hartford (I-91), Miami (I-95), and Houston (I-10) used narrow lanes and shoulders during construction. In each case, it was decided that adequate work space could be developed without closing lanes (other than on a temporary basis during off-peak conditions) and that the alternative routes and modes did not have sufficient unused capacity to accommodate significant diversion from the construction zone. Consequently, project planners and engineers developed construction phasing sequences and traffic control plans that maintained the same number of travel lanes during construction as existed before construction.

Boston. In Boston, I-93, the Southeast Expressway, is the only major highway facility connecting Boston with southeastern Massachusetts. The Expressway is a six-lane freeway facility with a shoulder in each direction used as a travel lane during peak hours. It carried more than 160,000 vehicles per day (vpd) before construction. An 8.5-mi section of the Expressway was reconstructed during the construction seasons (March through November) of 1984 and 1985 (4-6). During construction, the Expressway was divided into four two-lane segments, and work was allowed 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 a reversible, express roadway for through traffic. This plan provided four travel lanes for peak direction traffic, the same number as before construction, and two lanes for off-peak direction traffic. Portable concrete barriers (PCBs) were used extensively throughout the project to separate the work activity from traffic, as well as to separate opposing traffic flows. Paddle screens were also used to reduce driver "rubbernecking." The use of PCBs, paddle screens, ramp closures, and the reversible express lanes allowed traffic to operate at slightly higher speeds than existed before construction.

A number of improvements were made to alternative routes and modes in the freeway corridor prior to and during the construction project. Improvements to alternative routes included traffic signal and pavement marking changes as well as temporary police control at critical intersections. Improvements were also made to commuter rail, boat, and bus service. Employer-based ridesharing and flextime work programs were encouraged to reduce traffic demands. Finally, an extensive public information and community liason program was established for the project.

TABLE 3.1. TRAFFIC-HANDLING OPTIONS USED AT THE CONSTRUCTION PROJECTS REVIEWED

	Narrow Lanes and Shoulders	Lane Closures	Total Freeway Closures
Boston	X		
Minneapolis	X		
Hartford	X		
Miami	X		
Houston	X		
Chicago		X	
Pittsburgh		X	
Seattle		X	
Philadelphia		X	
Milwaukee		X	
Syracuse			X
Detroit			X

Minneapolis. I-394 is a new segment of Interstate highway being built along the alignment of existing US 12, which is the principal arterial highway linking the western suburbs with downtown Minneapolis (7). The western portion of the 11-mi segment of US 12 was a four-lane divided highway with several at-grade intersections, and the eastern portion was a six-lane freeway. I-394 will ultimately be a six-lane freeway with two reversible, high-occupancy vehicle (HOV) lanes. In 1984, the average annual daily traffic (AADT) on US 12 ranged from 49,000 vpd near the western end to 99,000 vpd at its highest volume location. During construction, two through lanes of mixed traffic are being provided in each direction, the same as existed before construction on the western end of the roadway. To accomplish this, the project was divided into eight major segments that will be completed over an eight-year period (1985-1992). 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. PCBs are being used extensively within the construction zone throughout the project. It has been estimated that where the detours and bypasses have involved additional signalized intersections for US 12 traffic, the capacity of the roadway has been reduced by up to 25 percent (7).

Very little capacity was believed to be available on the two principal alternative routes in the corridor. A number of traffic signal, intersection widening, and pavement resurfacing improvements were made on one of the routes prior to the start of the construction project. It should be noted that these improvements had been programmed as part of the overall transportation plan for the city, and were scheduled for completion prior to the I-394 project. However, the traffic management action receiving the most publicity during construction was the introduction of an interim HOV lane in the median of the existing facility (8). The lane was initiated during construction not only to provide additional people-moving capacity through the construction zone, but also to begin to get people accustomed to the idea of HOV lanes. To coincide with the introduction of the HOV lane, improvements were made to bus service in the corridor, ridesharing programs were expanded, and a free temporary HOV parking lot was established for carpoolers. A public information campaign was established to encourage motorists to use HOVs or to avoid the construction zone. The reduced roadway capacity at the signalized intersections and the promotion of alternative routes and modes has resulted in some diversion during construction. Traffic volumes on US 12 have been 10 to 15 percent lower during construction (12).

Hartford. I-91 is a north-south, four-lane divided highway that connects the cities of Hartford, Connecticut and Springfield, Massachusetts. As of 1982, this section of I-91 carried more than 180,000 vpd. I-91 is currently undergoing construction from Hartford north to the Connecticut-Massachusetts state line, a distance of 19.5 mi. An additional traffic lane will be added in each direction, and a physically-separated HOV lane will be added in each direction of the southern 11-mi portion of the freeway (10,11). The project is scheduled in several phases over an eight-year time span. The goal of project engineers is to maintain two travel lanes in each direction. However, because of the proximity of the work areas and "rubbernecking" by motorists, capacities are predicted to be as low as 1250 vehicles per hour per lane (vphpl) within sections of the construction zone. In order to accommodate as much as 1500 vph that may divert from the freeway, several impact mitigation actions were identified and evaluated for implementation within the I-91 corridor. These actions include resurfacing, intersection widening, and a computerized traffic signal system on alternative routes; expanded commuter rail and express bus service; a new ridesharing promotion; additional park-and-ride lot capacity; and freeway ramp metering. The improvements on the alternative routes were already scheduled to be performed as part of the overall transportation improvement plan for the corridor. The rail service and ramp metering were not implemented because the analysis determined they were not warranted. However, the possibility of implementing them has been left open if conditions on the freeway become significantly worse than expected.

Miami. In Florida, the construction of a 44-mi segment of I-95 between Boca Raton and Miami began in 1987 and is scheduled for completion in 1991 (13). The existing six-lane freeway will be expanded to 10-12 lanes, of which two will be HOV lanes. The traffic control plan for the project will retain six travel lanes during construction. Lanes will be narrowed and, in some segments, shoulders will be narrowed or eliminated. Lane closures will be permitted only at night. A corridor traffic management plan was developed and implemented for the construction project. The plan included improvements on alternative routes (roadway and intersection improvements, computer-controlled traffic signal system); travel demand management measures (region-wide commuter ridesharing matching program, variable work hour promotions); transit improvements (principally a new commuter rail service timed to coincide with the start of construction); and a public information program (regional signing plan and travel advisory radio in addition to traditional public information techniques). The major work on the main lanes of I-95 is scheduled to begin early in 1989; therefore, as of this writing, the most severe travel impacts have yet to be experienced.

Houston. The construction of the I-10 Katy Freeway in Houston exemplifies the use of narrow lanes and shoulders in Texas. The Katy Freeway is a major Interstate highway between downtown Houston and its western suburbs. A construction project on the Katy Freeway during 1983 and 1984 included retrofitting the freeway with a barrier-separated median HOV lane and rehabilitating the main lane pavements (13). The freeway cross section varied from six lanes at the western end of the project to eight lanes at the eastern end. Traffic volumes on this section of freeway (during 1982) varied from 135,000 to 186,000 vpd. The project contract required that the number of lanes on the freeway during peak periods be the same during construction as before. Temporary lane closures were permitted only during off-peak periods. The existing cross section included 10-ft median and outside shoulders, and 40- to 50-ft outer separations to one-way frontage roads. Work areas were created in the median and on the inside and outside edges of the main lane. Traffic was routed around the work areas in 10- to 11-ft lanes with no shoulders on either side (13). Work areas and travel lanes were separated by PCBs. Entrance and exit ramps in active work areas were closed as necessary. No improvements were made to alternative routes and modes during this project. Studies showed that traffic volumes and speeds were maintained at nearly pre-construction levels during the project (13).

Partial Closures

As indicated in Table 3.1, there have been several construction projects during which one or more travel lanes were closed to traffic for several months or more (I-94, Edens Expressway, in Chicago; I-376, Parkway East, in Pittsburgh; I-76, Schuylkill Expressway, in Philadelphia; I-5, Ship Canal Bridge, in Seattle; and I-94, Milwaukee). While the projects discussed in the previous section had temporary lane closures during off-peak time, the projects in this category involved lane closures that remained in place 24-hours a day for several months. In most instances, substantial improvements on alternative routes and modes were made to accommodate the large amounts of traffic expected to divert from the construction zone.

Chicago. I-94, the Edens Expressway, is a six-lane freeway which serves as the principal arterial through the north shore suburbs of Chicago. Traffic volumes before construction ranged from 57,000 vpd at the north end of the project to 135,000 vpd at the southern connection with the Kennedy Expressway (I-90). A construction project was undertaken on a 15-mi segment of the Expressway during the construction seasons of 1978 through 1980 (14-17). During construction, one directional roadway of the Expressway was closed at a time, and four-lane, two-way traffic was maintained on the other directional roadway. This traffic control plan resulted in a 33 percent reduction in the number of available freeway lanes. PCBs separated opposing traffic and workers from the travel lanes. A 35-mph speed limit was established through the construction zone because of reduced lane widths, narrow or no shoulders, proximity of construction operations to traffic, low-speed temporary ramp connections, and frequent changes in ramp closures. No improvements were made to alternative routes in the corridor. However, transit and park-and-ride lot capacity were increased slightly for construction.

Although traffic volumes in the construction zone decreased by about 30 to 35 percent during construction, very little increase in transit was observed. A large proportion of the diverted traffic was traced to an increase in volumes on a parallel freeway six miles away. It was assumed (although not verified) that the other diverted traffic used arterial routes, cancelled their trips, or used other freeways in the area.

Pittsburgh. I-376, the Parkway East, is the only major east-west freeway connecting downtown Pittsburgh with the Pennsylvania Turnpike (I-76) and eastern suburbs. The facility is a four-lane freeway, including the 0.8-mi, double-bore Squirrel Hill Tunnel. The freeway carried 132,000 vpd through the section rehabilitated, including 80,000 vpd through the tunnel. A construction and safety update project was performed on a 6.5-mi section of the freeway during 1981 and 1982 (18-20). The traffic control plan used during most of the project was to close one directional roadway of the freeway at a time, (inbound in 1981 and outbound in 1982) and to maintain two-lane, two-way traffic on the other directional roadway. PCBs separated traffic from the work area. The entrance ramps within the construction zone were closed and the entrance ramp nearest each end of the construction zone was restricted to HOVs. Individual exit ramps were closed when required by work activities.

The only alternative routes in the corridor were arterial streets, many of which were already congested. Consequently, several improvements were made both to alternative routes and to alternative travel modes. The Parkway East was the first project for which FHWA authorized the use of Interstate funds to help relieve increased congestion on other routes in a corridor caused by the construction of an Interstate (21). The improvements to alternative routes included traffic signal installation and coordination, left-turn prohibitions, parking restrictions, widening, and signing/lighting improvements. In addition, police officers were used at critical intersections for traffic control during peak periods. Other improvements included a new commuter rail service, expanded express bus service, vanpool promotions, and new or expanded park-and-ride lots.

Philadelphia. I-76, the Schuylkill Expressway, is the major east-west freeway connecting downtown Philadelphia with the Pennsylvania Turnpike and western suburbs. The 21-mi long freeway is predominantly four lanes wide, although several segments near downtown have six or eight lanes. Traffic volumes ranged from 80,000 vpd near the Turnpike to 143,000 vpd near downtown. Construction of an 18-mi segment of the Expressway began in 1985 and is scheduled for completion in 1989 (22-24). Two lanes of traffic were constructed at a time. In the four-lane segments, two-lane two-way traffic was maintained on one directional roadway while work was performed on the other directional roadway. The outside shoulders were upgraded to allow traffic to operate on the shoulder and the median lane with a buffer lane in between. The reduction in the typical cross section from four to two lanes translated into a 50 percent reduction in available freeway lanes. Most of the entrance ramps and some of the exit ramps within or leading to the construction zone were closed during construction.

A number of improvements were made to alternative routes to accommodate the diverted traffic. Existing traffic signals were modernized, retimed, and coordinated, and new temporary and permanent signals were installed at some locations. Some intersections were widened and on-street parking was eliminated on certain streets. Police officers were assigned to critical intersections and school bus stops for traffic control. Improvements were also made to transit and ridesharing programs in the corridor. Analysis of the impacts of the project are ongoing. However, a 60 percent reduction in freeway volumes was observed in the first construction season, suggesting that substantial diversion occurred.

Seattle. I-5 is the major north-south freeway through Seattle. It includes an eight-lane freeway and a separate two-lane reversible roadway for express lanes, which runs north from the central business district for 8 mi. The main lanes of the Ship Canal Bridge and the Lakeview/Galer Viaduct were resurfaced during the summers of 1984 and 1985 (25,26). Traffic volumes on this section of the freeway was 210,000 vpd. The basic traffic control plan involved closing two lanes at a time in a given direction, and maintaining traffic on the two remaining lanes. It was apparent to project planners that normal traffic volumes could not be accommodated on only two travel lanes. Therefore, a coordinated effort was undertaken to reduce the volumes on I-5 and to minimize the adverse impact on motorists. Traffic signals were retimed and police officers were used for traffic control at critical intersections on alternative routes in the corridor. New bus routes were added to the transit system, and two entrance ramps in the downtown area were restricted to HOV vehicles only. Information on carpooling was distributed to the public.

Traffic volumes on I-5 decreased by 38 to 40 percent during construction. Much of the diverted traffic was traced to the express lanes or one of five principal alternative routes in the corridor. In addition, bus ridership was slightly (10 percent) higher during construction.

Milwaukee. A major three-year construction was initiated in 1987 on a 5-mi section of I-94 immediately south of downtown Milwaukee (27). This segment of I-94 is the principal route from the south into downtown, carrying approximately 125,000 vpd into and out of Milwaukee. As part of the construction project, the 4000-ft bridge forming the southern leg of a complex freeway-to-freeway interchange underwent bridge deck replacement. The bridge consists of two independent structures (one per direction), each four lanes wide. The basic traffic control plan for this project was to close one bridge structure at a time, and to maintain two lanes per direction on the other bridge structure (accomplished through crossovers from one roadway to the other at each end of the bridge). This 50 percent reduction in the number of available freeway lanes was expected to cause significant diversions to alternative routes and modes in the corridor.

Improvements were made to alternative routes (signal timing changes, signing and marking improvements, parking restrictions, and temporary signal installations), school and pedestrian crossings (additional school crossing guards, a pedestrian safety information program), and transit (additional transit service on local streets, express freeway flyer routes, increased marketing and promotion efforts). In addition, public information programs were established, and extra enforcement and tow truck service were provided on the freeway to reduce incident response and removal time. Other actions included freeway ramp closures and ramp restrictions of others to HOVs during peak periods. A planned detour route was also established to route through traffic around the construction project.

Traffic volumes on the freeway bridge declined more than 50,000 vpd during 1987 construction. Much of this traffic was traced to alternative local streets in the corridor or to the designated detour routes. Only a small increase in transit was observed during construction. Despite the reductions in capacity on the freeway, travel times through the construction zone were the same as before construction. Travel times on alternative routes increased only one to two min during construction.

Total Freeway Closures

Two freeway construction projects to date have involved the total closure of one direction of the freeway, those being I-81 in Syracuse, and US-10, the Lodge Freeway, in Detroit.

Syracuse. I-81 is a major north-south freeway running through Syracuse, New York. Traffic on the four-lane freeway had reached 70,000 vpd by the 1970's. Because of this, two travel lanes were added to a 10-mi segment of the Interstate and three major interchanges were modernized (28,29). Throughout most of the project the basic traffic control plan involved only narrowed lanes and shoulders and occasional temporary single-lane closures. However, in 1984, bridge deck rehabilitation and substructure repairs required the total closure of the 2.8 mi, three-lane viaduct and adjacent structures carrying southbound traffic through the I-81 interchange with I-690. It was also necessary to close one northbound lane and slow traffic on the remaining northbound lane to 30 mph in order to minimize damaging vibrations during construction of the southbound structure.

A package of improvements on alternative routes and modes was implemented to offset the traffic congestion caused by the southbound closure. The improvements on alternative routes included traffic signal improvements and police officers for traffic control at key locations. Improvements in bus transit and HOV services included expanded park-and-ride lots, express bus service between the park-and-ride lots and downtown locations, an exclusive HOV lane on an alternative route, and expansion of an existing carpooling program to handle additional requests for ridesharing matches.

Syracuse is a mid-sized city and the amount of traffic is much smaller than in the other metropolitan areas discussed in this report. Therefore, the alternative routes in the corridor, with the improvements in traffic signal timing and coordination, were able to accommodate most of the traffic forced to divert from I-81. A small increase in transit and HOV usage was initially observed, but usage tapered off during the closure.

Detroit. The Lodge Freeway is a six-lane freeway connecting downtown Detroit and its northwestern suburbs. Prior to construction, the traffic volume on the freeway was approximately 125,000 vpd at the highest volume location. An 8.4 mi section of the freeway was reconstructed during the 1986 and 1987 construction seasons (April through November) (30,31). Since considerable unused capacity existed on nearby parallel freeways and arterials, the traffic control plan adopted for the second year of construction was the total closure of one direction of the Lodge Freeway at a time with traffic diverted to designated alternative routes. In 1986, the work did not directly involve the travel lanes and, therefore, the freeway capacity reductions were minor. During 1987, the northbound (outbound) lanes were closed from April through July, and the southbound (inbound) lanes were closed from July through October. Traffic in the closed direction was diverted to alternative routes and modes.

A few improvements were made to alternative routes. One route was resurfaced, signing and lighting was improved, and traffic signals were retimed. There were attempts to increase carpooling during construction. Also, bus service was expanded in the corridor during construction. Little increase in bus usage was detected, however. The improvements on alternative routes were more worthwhile. Traffic volumes increased on most of the alternative routes without causing significant increases in travel times.

Techniques to Improve the Capacity of the Construction Zone

One of the primary goals of a traffic management plan is to optimize the capacity of the construction zone for the selected traffic control plan. A number of techniques that have been used to improve the capacity of the construction zone (for a given traffic control plan) are reviewed in this section. These include:

1. Portable concrete barriers and paddle screens to separate work areas from travel lanes or to separate opposing lanes of traffic,

2. Entrance ramp closures and/or restriction of ramps to HOVs,

3. Widening and upgrading shoulders for use as temporary travel lanes,

4. Reversible lanes for peak period, peak direction traffic, and

5. Incident management techniques to reduce incident detection and response times.

Table 3.2 summarizes the techniques used during each of the projects reviewed in this report.

Portable Concrete Barriers

As Table 3.2 illustrates, PCBs have been utilized at nearly every major construction project to date. Concrete barriers have been used primarily for safety reasons, separating the work area from the travel lanes, separating opposing traffic flows, or separating HOV traffic from mixed-use traffic. However, barriers also promote smoother traffic operations and help optimize the available work space and the roadway capacity of a construction zone by allowing traffic to operate adjacent to the work area with little or no buffer area. For example, the construction of I-10 (Katy Freeway) in Houston required narrow (10 to 11 ft) lanes, the elimination of inside and outside shoulders, and the placement of concrete barrier immediately adjacent to the narrowed travel lanes. Even with these tight space limitations, capacities within the construction zone averaged 1750 vphpl (12).

Paddle Screens

Paddle screens are used to reduce driver distractions in the construction zone, which in turn should result in lower accident frequencies and improved traffic operations. To date, two projects (Boston and Miami) have utilized or will be utilizing paddle screens. Costs of paddle screens vary depending on the type and amount used. For example, approximately $600,000 (in 1987 dollars) was spent on paddle screens in Boston for the 8.3-mi construction zone ($72,300 per mile). Paddle screens were also proposed as part of the I-95 construction in Miami. It was estimated that leasing 23.5-mi of paddle screens in Florida would cost $3,274,000 (1987 dollars), for an average cost of $139,000 per mile.

TABLE 3.2. SUMMARY OF TECHNIQUES TO OPTIMIZE CONSTRUCTION ZONE CAPACITY

Location	Portable Concrete Barrier	Paddle Screens	Long-Term Ramp Closures	HOV-Only Ramps	Temporary Shoulder Lanes	Reversible Lanes	Incident Management Techniques
Boston	X	X	X		X	X	X
Minneapolis	X					X[a]	
Hartford	X						
Miami	X	X	X				X
Houston	X		X		X		
Chicago	X		X		X		X
Pittsburgh	X		X	X	X		X
Seattle	X			X		X	X
Philadelphia	X		X		X		X
Milwaukee	X		X	X			X
Syracuse	X		X				
Detroit	X		X				X

[a] Reversible lane was for HOVs only

It was felt that the screens facilitated traffic flow through the I-93 construction zone in Boston (6). The combined system of PCBs, paddle screens, and the reversible express lanes resulted in better traffic flow than existed prior to the start of construction. In Miami, it was predicted that the screens would result in travel time, vehicle operating cost, and accident cost savings of about $13,500,000 during the 5-year project, for a benefit-cost ratio of 4:1. Since the bulk of the main lane work in Miami has yet to begin, it is not known whether the assumptions used in this analysis (changes in travel time, operating costs, or accident costs due to the screens) will actually be realized.

Ramp Closures or Restriction to HOVs

Temporary ramp closures and the restriction of ramps to HOVs are two other techniques that have been used during construction which can maximize traffic flow and roadway capacity. Both techniques reduce traffic demands on the freeway and also eliminate vehicle merging conflicts. Furthermore, restricting ramps to HOV usage may also promote HOV utilization during construction.

The effectiveness of ramp closures and restrictions is site-specific, dependent upon such items as:

1. Normal freeway and ramp volumes,
2. Ramp locations,
3. Freeway and ramp geometrics,
4. Origin-destination patterns of ramp users,
5. Current HOV usage, and
6. Operating conditions on the arterial streets in the corridor.

The costs of implementing ramp closures are generally minimal, limited to necessary signing and barricades. The principal costs associated with restricting ramps to HOV usage are for informing the public that the ramp is restricted to HOV use only and for enforcement.

Specific cost and effectiveness data for ramp closures and restrictions are available only for the I-376 construction project in Pittsburgh. During this project, signing and enforcement of two HOV-only ramps cost $750 per day (in 1987 dollars). The HOV ramps were located at the beginning of the narrow construction section (and downstream of the congestion that developed due to the restricted section). As a result, HOV users could bypass the congestion that developed on I-376. It was estimated that the ramps saved HOV travelers an average of 8 min per person trip. If these savings are summed over all

HOV modes (carpools, vanpools, and buses), one finds that the HOV ramps saved their users 2,900 hours of delay per day. Using a 1987 value of travel time equal to $8.03 per hr (32), this equates to a dollar savings for HOV users of more than $23,000 per day (benefit-cost ratio = 31:1). The HOV ramps were reported to have caused only a slight increase in travel time to non-HOV users, but the specific amount was not reported in the project documentation (18). It is not known what conditions would have been like had the ramps been used for normal mixed-flow operation or closed completely during construction. Consequently, the above estimate of savings is likely an overestimate of the actual overall benefits of HOV ramp operation. Nevertheless, the estimate does suggest that HOV ramps were cost-effective during the I-376 construction.

Utilizing Shoulders as Temporary Travel Lanes

Several projects have utilized shoulders as temporary travel lanes during construction. The costs of this technique include (1) the actual shoulder widening and upgrading work, and (2) possible increased accident and delay costs due to stalled vehicles or incidents that cannot be quickly moved to a shoulder. The benefits of shoulder usage come from (1) improved traffic operations by providing an additional travel lane, and (2) reduced construction time by allowing work to proceed on a greater portion of the roadway.

The trade-offs associated with shoulder usage as a travel lane during construction are not fully understood at this time, due to a lack of available data in this context. However, the effects of shoulder removal under normal urban freeway conditions have been investigated (33-35). The most recent results suggest that converting the inside shoulder to a travel lane does not appreciably increase accidents and may decrease them significantly on high-volume facilities (33,34). In addition, traffic flow is increased appreciably. On the other hand, the effect of converting an outside shoulder to a travel lane upon safety is not as evident. Again, traffic flow can be increased substantially, but a slight increase in accidents may occur. According to this research, however, converting both inside and outside shoulders to travel lanes in normal situations does not appear to be justifiable; accident rates may increase, and delays caused by incidents that cannot be moved to a shoulder may actually outweigh the benefits in improved traffic flow during non-incident conditions. However, as stated earlier, more research is needed to determine whether these actions are cost-effective in construction situations.

Reversible Lanes

In most cases, the maximum available freeway capacity is needed only during peak demand periods. Another technique to optimize the capacity of a construction zone is to use reversible lanes for peak-period, peak-direction traffic flow.

Reversible lanes should be considered only when traffic flows on the freeway during peak periods are unbalanced. Furthermore, there should be a significant amount of traffic traveling through the construction zone (i.e., not large amounts of entering and exiting traffic at ramps within the construction zone) that can utilize the reversible lanes. Consequently, this technique is likely to be more applicable to radial rather than circumferential freeways.

In Boston, barrier-separated reversible express lanes were used during the construction of I-93. During peak periods, this meant that two regular use lanes and two express lanes were available in the peak direction. Peak period travel times on the freeway were the same as or lower than before construction, even though little traffic diverted from the freeway. It was noted that the separation of express and local peak period traffic eliminated merging and diverging conflicts between these groups of drivers (6), which may explain why conditions were so favorable during construction.

Incident Management Techniques

A number of incident management techniques have been utilized to reduce incident detection and response times during construction. While the importance of quickly detecting and responding to freeway incidents is important to traffic operations in normal conditions, it often becomes even more vital during construction when shoulders are eliminated or converted to travel lanes, ramps are closed within the construction zone, and portable concrete barriers (used to separate traffic from the work area and to separate opposing traffic) limit access by emergency and service vehicles.

Five techniques have been used or proposed to reduce incident detection, response, and removal times during construction projects:

1. Providing free tow-truck service,
2. Initiating or increasing courtesy (or service) patrols,
3. Installing emergency phones for motorists,
4. Utilizing existing freeway surveillance systems, and
5. Increasing police patrols.

Table 3.3 identifies the projects where free tow truck service was provided during construction. Where available, cost and usage data are also provided. The number of calls handled per day varied from project to project in relation to the amount of traffic on the freeway and the number of tow trucks provided. As Table 3.3 indicates, the tow truck service cost approximately $150 to $200 per vehicle serviced for the Boston and Detroit projects, respectively. Unfortunately, data regarding the benefits of the service in terms of reduced motorist delay and accident potential have not been documented. The data for the Milwaukee project includes tow truck service and added enforcement within the construction zone. A total of $97,000 was spent in 1987 to assist 234 vehicles, for an approximate cost of $415 per vehicle. The projects in Philadelphia and Seattle also

TABLE 3.3. SUMMARY OF COST AND USAGE OF FREE TOW TRUCK SERVICE DURING CONSTRUCTION

	Vehicles Serviced	Days of Operation	Vehicles Serviced per Day	Total Cost[a]	Cost per Vehicle Serviced
Boston	12,383	287	43	$1,827,500	$147
Chicago	8,340	517	16	N/A	N/A
Seattle	N/A	N/A	N/A	N/A	N/A
Philadelphia	N/A	N/A	N/A	N/A	N/A
Milwaukee[b]	234	140	2	$97,000	$415
Detroit	2,935	454	6	$595,000	$203

[a] Costs are updated to 1987 dollars.

[b] Milwaukee employed both tow truck service and added enforcement within the construction zone. Available data includes both programs.

N/A Data Not Available

utilized tow truck service during construction; however, cost and usage data are not available.

Service patrols proposed for I-95 construction in the Miami area were predicted to cost approximately $425,000 (1987 dollars) during the 5-year project. It was predicted that the patrols would assist nearly 4,000 motorists and would reduce delays by 350 hours per incident. Thus, total motorist delay cost savings were anticipated to approach $9,800,000 for the project, yielding a benefit-cost ratio of 23:1.

Emergency motorist aid telephones were also proposed for the Miami area I-95 project. The telephone system is predicted to reduce incident detection time by an average of three min per incident. Total costs for the system were estimated to be $257,000, while benefits were predicted to approach $3,500,000. The resulting benefit-cost ratio was thus 13:1. Although both the emergency telephones and service patrols were recommended for use during I-95 construction, the estimates of the benefits for each assumed that only one technique would be present. Consequently, it is unlikely that both techniques implemented simultaneously would achieve the above benefit-cost ratios.

Construction projects in Seattle (I-5) and Chicago (I-94) made use of existing freeway surveillance and control systems to detect and respond to incidents within the construction zone. Although these experiences indicate that the systems were useful in maintaining acceptable traffic conditions during construction (14,25), no data are available on the additional benefits or costs of using these systems during construction.

Summary

Traffic control plans for freeway construction projects may be grouped into three categories: (1) narrow lanes and shoulders, (2) lane closures, and (3) total freeway closures. The experiences from the projects reviewed in this report suggest that each option can work effectively when implemented as part of a corridor traffic management plan. At those projects where it was possible to maintain the same number of lanes during construction by reducing lane and/or shoulder widths, reductions in traffic-handling capacity and associated travel impacts have been minor. Projects on heavily traveled freeways that have used long-term lane closures or total freeway closures have seen traffic volumes through the construction zone decrease by approximately the same percentage as the reduction in the number of available travel lanes.

TSM improvements on alternative routes and modes along with public information programs were implemented in conjunction with many of the projects. The effectiveness of these activities is seen by the fact that although traffic conditions through the affected corridors were degraded, public response to the projects was quite positive.

These results raise important issues regarding the selection of a traffic-handling strategy for a project. Feelings expressed at a recent conference on transportation management for major highway construction indicate that the least restrictive strategy that can be implemented should be chosen (1). Such an approach will, in general, minimize the severity of the impacts of construction upon the motoring public. However, the duration of construction must be increased, and temporary roadways and other actions to maintain this capacity increase the cost of the project. As an SDHPT project engineer stated, "Your construction time could be cut in half if you did not have to maintain traffic...You need to build three new roads instead of one" (36). As additional data regarding the impacts of construction projects within the corridor and the effect of improvements on alternative routes on modes are gathered, it will be possible to make better decisions regarding traffic management during major urban freeway construction and to select the most cost-effective traffic-handling strategy.

4. CATALOG OF TRAFFIC IMPACT MITIGATION ACTIONS

Critical to the success of the traffic management plans for those construction projects reviewed in this report has been the traffic impact mitigation actions that have been implemented. Traffic impact mitigation actions have included: (1) TSM-type improvements to increase the capacity and improve operating conditions on alternative routes in the corridor, and (2) TSM techniques to improve service and increase ridership on public transit and ridesharing alternatives. This chapter presents a catalog of techniques in both categories and summarizes available information on the costs and effectiveness of the various techniques.

Improvements on Alternative Routes

A variety of improvements have been used for increasing the capacity and improving operations on alternative routes affected by freeway construction projects. These improvements can be grouped into the following categories:

1. Traffic signal improvements,

2. Other intersection improvements, and

3. Other roadway improvements.

Experiences from those projects where significant capacity reductions were required on the freeway showed that the most common diversion response from drivers was to change routes. Consequently, the actions implemented on the alternative arterial routes were extremely important to maintaining adequate traffic movement through the corridor. Unfortunately, several factors make it difficult to provide specific cost and effectiveness data from these projects for individual techniques. In most cases, several actions were implemented simultaneously such that only the combined effectiveness of the actions is evident. In other cases, costs cannot be accounted for because the actions were implemented as part of other planned improvements not directly associated with the construction project. Finally, records of the costs and effectiveness of the actions for some of the projects were not accessible for review or evaluation.

Traffic Signal Improvements

Along most urban arterials, signalized intersections are the primary restrictions to the flow of traffic. Signalized intersections limit the overall traffic-carrying capacity of the alternative routes in the corridor and, thereby, the ability to accommodate large amounts of diverted traffic during major freeway construction. Consequently, actions to accommodate additional traffic at signalized intersections have been vital to the successful management of traffic during many construction projects.

Two basic types of improvements have been made at signalized intersections on alternative routes as part of previous construction projects:

1. Adjustments in signal timings and phasings, and

2. Improvements in signal equipment (installation of temporary traffic signals, traffic-actuated signals, time-based coordination, and computerized traffic control systems).

Table 4.1 indicates the types of traffic signal improvements made at the projects reviewed in this report. As can be seen, signal timing changes have been necessary on alternative routes at most of the projects to accommodate anticipated traffic diversion from the freeway construction zone. In some cases, the timing adjustments have improved signal coordination, resulting in higher speeds on the alternative routes during construction than before construction.

Relative to most other TSM actions, costs of signal timing changes are minor, yet can result in significantly improved traffic operations at the intersections and along the entire arterial. For example, timing adjustments of approximately 30 signals in Syracuse during I-81 construction reportedly cost $28,500 (28) (updated to 1987 dollars) at an average cost of $950 per intersection. Specific data as to the benefits of timing adjustments were not available, although the arterials were reportedly able to handle a significant amount of diverted traffic without dramatic increases in travel times. Although not in a construction context, experiences of a statewide signal retiming program in North Carolina provide an indication of the operating cost savings possible through signal timing improvements. Approximately 750 of the state's traffic signals were retimed at an average cost of $481 per intersection, which produced average operating cost savings of $51,815 per intersection per year and yielded a benefit-cost ratio of 108:1 (37). These intersections were determined beforehand to have been those most needing adjustment, so the benefits achieved were quite substantial. Nevertheless, the data does show the potential for dramatic improvements in operations at a fairly small cost.

Signal timing equipment has also been upgraded to improve operations on the alternative routes at some of the projects. Traffic-actuated controllers, time-based coordinators, and even central computerized signal control systems have been implemented on alternative routes prior to construction. This equipment has allowed greater flexibility in providing time-of-day changes in signal timings and improved progression along the arterial route(s). The improvements made for the Minneapolis and Hartford projects were made as part of the overall transportation plan for the area, and were not directly funded through the freeway construction project. For other projects, the improvements were made specifically to handle the increased traffic on the arterials due to freeway construction. Many projects have installed temporary signals at previously unsignalized intersections. In contrast, signals at two locations in Syracuse were deactivated in order to improve operations on an alternative route (28).

Again, little specific data exist as to the costs and effectiveness of traffic signal improvements during construction. However, methodologies are available for making

TABLE 4.1 SUMMARY OF TRAFFIC SIGNAL IMPROVEMENTS ON ALTERNATIVE ROUTES

	Adjustments in Signal Timings	Changes in Traffic Signal Equipment
Boston	X	X[a]
Minneapolis		X[b]
Hartford		X[b]
Miami	X	X
Houston		
Chicago		
Pittsburgh	X	X
Seattle	X	
Philadelphia	X	X
Milwaukee	X	X
Syracuse	X	X[a]
Detroit	X	

a It is not known whether the traffic signal improvements at these projects included signal timing adjustments, changes in traffic signal equipment, or both. Hence, both actions are shown.

b These improvements were already scheduled as part of the overall traffic management plan for the city, and were not implemented solely for the construction project.

these estimates (38-40). The effect of the improvements will depend upon changes in traffic volumes and turning percentages, roadway geometrics, the operations of other nearby traffic signals, the type of equipment being replaced, and operating conditions at the intersection(s) before the improvements were made. As mentioned in several of the project reports, the improvements in traffic signal hardware will continue to provide benefits to the public even after the construction project is completed.

Other Intersection Improvements

Other improvements have also been implemented at intersections on alternative routes during freeway construction projects, including:

1. Temporary left-turn prohibitions,
2. Intersection channelization to add turning bays,
3. Intersection widening, and
4. Police officer control of intersections during peak periods.

Table 4.2 summarizes the other intersection improvements made at the construction projects reviewed. The costs and effectiveness of these actions vary from site to site, depending upon factors such as existing traffic volumes, the amount of traffic diverting from the construction zone, existing geometrics, turning movements, and intersection operating conditions before the improvements. In general terms, turning prohibitions are the least costly to implement, requiring mainly signing changes and some enforcement. Channelization and widening are more capital-intensive, but will continue to provide benefits after the construction project is completed.

Police officers have been used at key intersections during peak periods at many of the projects. Police control has been useful at the beginning of projects when it is difficult to know exactly what the impacts of construction will be upon alternative routes in the corridor. In some cases, the number of officers used was reduced dramatically after the first two or three weeks of the project, as the problems anticipated at the intersections never materialized or dissipated over time as drivers found other travel routes. Police control is labor-intensive and costly to implement. In Pittsburgh, police control of 17 signalized intersections during peak periods cost more than $17,600 per week (1987 dollars), for a total cost of $633,600 for the project (18). In Syracuse, nearly $105,000 (1987 dollars) was spent on police control of critical intersections over the 4.5 month construction period of I-81 (28). Police use on alternative routes in Boston (I-93) was budgeted at $438,000 (1987 dollars) for the two-year project (6).

TABLE 4.2. SUMMARY OF OTHER INTERSECTION IMPROVEMENTS ON ALTERNATIVE ROUTES

	Left-Turn Restrictions	Intersection Widening and Channelization	Police Control
Boston			X
Minneapolis		X	
Hartford		X	
Miami	X	X	
Houston			
Chicago			
Pittsburgh	X	X	X
Seattle			X
Philadelphia		X	X
Milwaukee			
Syracuse			X
Detroit			

Other Roadway Improvements

The final category of improvements to alternative routes are those made along all or part of an arterial. Included in this category are the following:

1. Creating a reversible lane on a route,
2. Converting streets to alternating one-way pairs,
3. Pavement marking and striping changes to add additional travel lane(s) or to assist motorists who divert from the freeway,
4. Parking prohibitions,
5. Pavement improvements to increase speeds and handle additional traffic, and
6. Signing and lighting improvements to aid motorists who divert from the construction zone.

Table 4.3 summarizes the actions used at the construction projects reviewed in this report. Because these actions have generally been implemented in conjunction with signal timing and other intersection improvements, it has not been possible to determine their incremental effectiveness during freeway construction. Experiences at the previous projects do indicate, though, that the overall packages of improvements on alternative routes have increased the capacity of the arterials to accommodate the diverted traffic from the construction zone without substantial increases in congestion levels. In Detroit, for example, signal timing and other roadway improvements allowed two arterials to handle 40 to 60 percent more traffic with little or no increase in travel times (31).

Summary

Experiences at past construction projects have shown that key improvements along alternative routes in the corridor can enable the routes to accommodate considerable increases in traffic without causing serious delay and congestion. In general, these actions have been more important at locations where long-term lane closures or total freeway closures in the construction zone have been used and where significant diversions to the alternative routes have occurred. If the project requires only narrow lanes or shoulders in the construction zone, less diversion to alternative routes is likely and improvements along those routes will not be as critical.

The costs of improvements on alternative routes vary widely. Some improvements, such as signal timing changes, are inexpensive and require only a one-time cost to develop and implement. Other actions, such as police control of intersections, require continuous funding for as long as the action is used. Actions such as intersection widening, channelization, and changes in signal equipment are more capital-intensive, but continue to provide benefits to the public even after the project is completed.

TABLE 4.3. SUMMARY OF OTHER ROADWAY IMPROVEMENTS ON ALTERNATIVE ROUTES

	Reversible Lanes	Converting Streets to Alternating One-Way Pairs	Pavement Marking and Striping Improvements	Parking Prohibitions	Resurfacing or Pavement Repairs	Signing and Lighting Improvements
Boston			X			
Minneapolis					X	
Hartford					X	
Miami	X	X	X			X
Houston						
Chicago						
Pittsburgh				X	X	
Seattle						
Philadelphia					X	
Milwaukee				X	X	X
Syracuse						
Detroit					X	X

From a practical standpoint, the less expensive techniques (signal timing changes, temporary signals, left-turn and parking prohibitions, pavement repairs, and lane restriping) should be given first consideration. Computerized signal control systems or major intersection and arterial widening can provide substantial benefits in terms of reduced road user costs during construction. Because of their higher costs, though, they may not be cost-effective based solely on benefits during the construction project. However, since these improvements will remain in place after the project is completed, the cost-effectiveness evaluation should include the post-construction benefits. An approach utilized at some of the previous projects has been to accelerate the implementation of improvements already planned for alternative routes so that they are in place before construction begins.

In Texas, the presence of continuous frontage roads presents unique opportunities for accommodating traffic during construction. The frontage road provides a convenient alternative route for drivers. In the event of incidents or temporary lane closures, drivers can utilize the frontage road to bypass congestion if they so desire. Also, ramp closures required for construction purposes are less disruptive to drivers who can travel along the frontage road to the next available ramp. On the other hand, the proximity of the frontage road also presents considerable challenges in terms of maintaining adequate travel conditions, especially at diamond interchanges where interactions of two closely-spaced signalized intersections are quite complex. In certain situations, changes in traffic patterns at these intersections may dramatically affect the performance of the interchange and adversely impact frontage road, cross streets, and even freeway operations if appropriate adjustments are not made.

Any of the above improvements on alternative routes would be appropriate for use in Texas. However, before selecting improvements it will be necessary to estimate the traffic impacts of construction upon alternative routes. In cases where travel lanes can be maintained (at least during peak periods), it is unlikely that significant impacts would extend beyond the frontage roads. Long-term lane closures or total freeway closures, on the other hand, might affect operations on alternative routes several miles from the construction section.

Techniques to Increase Public Transit Ridership and Ridesharing

Officials at past projects have placed a strong emphasis on reducing travel demand through the construction zone by encouraging motorists to shift trips to public transit or to other HOV modes. Large sums of money have been spent to promote and upgrade these modes of travel during freeway construction. The efforts to promote these services have included:

1. New or expanded commuter rail service,
2. Expanded rapid transit (subway) service,
3. New or expanded bus service,

4. Introduction of HOV ramps or HOV lanes on the freeway or alternative routes,

5. New and expanded commuter park-and-ride lots, and

6. New or expanded ridesharing programs.

Table 4.4 illustrates the techniques implemented at each of the construction projects reviewed. In Boston, a commuter ferry boat service was also improved and heavily promoted. However, given the limited application of ferry boat service at other construction projects, no additional discussion is provided. Reference can be made to the project documentation if additional information is needed (5).

New or Expanded Commuter Rail Service

A number of actions have been taken at previous construction projects to divert trips from the construction section to commuter rail service. These techniques include:

1. Introducing new commuter train service,

2. Adding cars to existing trains,

3. Adding entire trains to existing lines to increase service frequency, and

4. Extending rail service beyond the existing limits of service.

As Table 4.4 indicates, commuter rail service was proposed, initiated, or expanded in six cities (Boston, Hartford, Miami, Chicago, Pittsburgh, and Philadelphia) as part of the traffic management plan during construction. Table 4.5 summarizes the available cost and effectiveness data for these projects.

In Boston, rail service was already near capacity before construction began. Approximately $4,000,000 (1987 dollars) were spent to increase capacity and service during I-93 construction. However, ridership increased only 395 person-trips per day during construction, resulting in a cost of $20 per person-trip. Survey data indicated that about 79% of this increase was due to drivers or carpoolers diverting from the expressway (the rest diverting from alternative routes or modes). One explanation for the small increase was that freeway capacity during peak periods was maintained at, or even above, preconstruction levels. Consequently, there was little incentive for commuters to divert from the freeway to the rail service.

In Pittsburgh, a 30 mile commuter rail line was initiated during construction. Existing railroad right-of-way and tracks were used, but trains and other operating equipment had to be purchased. Total costs for introducing this service were approximately $2,236,000 (1987 dollars). Despite intensive promotion efforts, the train

TABLE 4.4. SUMMARY OF PUBLIC TRANSIT AND RIDESHARING IMPROVEMENTS

	New or Expanded Commuter Rail	Expanded Rapid Transit Service	New or Expanded Bus Service	HOV Ramps and Lanes	New or Expanded Park-and-Ride Lots	New or Expanded Ridesharing Programs
Boston	X	X	X		X	X
Minneapolis				X	X	X
Hartford	X[a]		X	X[b]	X	X
Miami	X				X	X
Houston						
Chicago	X				X	
Pittsburgh	X		X	X	X	X
Seattle			X	X		X
Philadelphia	X		X		X	X
Milwaukee			X	X		
Syracuse			X	X	X	X
Detroit			X			X

[a] Commuter rail was proposed but not implemented.

[b] HOV lanes may be opened to traffic during construction (tentative).

TABLE 4.5. SUMMARY OF COST AND EFFECTIVENESS OF COMMUTER RAIL SERVICE

	Costs[a]	Estimated Increase in Ridership (person-trips per day)	Cost per Trip
Boston	$3,928,000	395	$19.89[b]
Hartford	$2,600,000	200	$13.00[c]
Miami	$66,900,000[d]	N/A	N/A
Chicago	N/A	N/A	N/A
Pittsburgh	$2,236,000	495	$24.82
Philadelphia	N/A	1300	N/A

[a] Costs are updated to 1987 dollars

[b] Operated over a 2-yr period

[c] Operated for 182 days

[d] Estimated based on projected ridership and costs over a 5-yr period

N/A Data Not Available

attracted an average ridership of only 495 person-trips per day (18), resulting in an average cost of approximately $25 per person-trip. Further analysis indicated that some of these trips were attracted from other travel routes in the area, and that only 200 vehicle-trips per day were actually diverted from the construction zone. Hence, the service cost $60 for every vehicle-trip diverted from the construction zone. After 182 days of service, the commuter train was discontinued. Several possible reasons were given for the poor showing of the rail service, including limited service (only two round trips per day), the initiation of express bus service that competed for the same customers, and little savings in overall trip time compared to the automobile (18).

Existing rail service was also expanded in Chicago and Philadelphia. In Chicago, little increase in ridership was detected during construction (14). Ridership in Philadelphia increased approximately 1300 person-trips per day on one of the lines. Unfortunately, cost data from these projects are not available.

The I-91 task force, in planning for the construction project on I-91 in Hartford, examined the possibility of expanding rail service to include an existing AMTRAK rail line as an additional commuter rail line. Annual operating costs were predicted to be $650,000 per year (11). Ridership estimates indicated 200 person-trips per day could be diverted to the service (assuming that it would be heavily utilized). As a result, it would cost approximately $13 per person-trip to implement the service. Planning officials decided not to implement the rail service, but left open the possibility of initiating the service in the future if conditions on I-91 degrade to the point that rail service becomes attractive.

A peak-period rail service was scheduled to begin in conjunction with the I-95 construction project in Miami. The rail service connects the region's three major airports and the county's public transit systems. It is estimated that the service will require $66.9 million in capital costs, and an additional $8.6 million in annual operating costs. No ridership estimates have been published.

In summary, the initiation or expansion of commuter rail service is costly. It appears that the use of this travel mode by commuters will depend primarily on conditions within the construction zone. The service must provide a recognizable benefit to the motorist in order for it to attract trips away from the construction zone. Experiences with commuter rail in Pittsburgh and Boston showed limited use because the service provided little travel time benefit to the commuter over automobile use. However, the more substantial increase in ridership during the construction efforts of Philadelphia suggests that the possibility does exist for the effective use of this travel mode.

Expanded Rapid Transit Service

In Boston, a rapid transit system was already in place prior to the start of I-93 construction. Feeder bus service to terminal stations along the system was increased to promote diversion to rapid transit. During the first year, little or no change in ridership was detected. However, it was estimated that an additional 1700 passenger-trips per day utilized the system during the second year. Further, it was noted that the majority of the increase was traced to terminals at the southern (outer) end of the system. From these data, it was concluded that the increase was likely due to drivers diverting from the expressway to rapid transit. However, factors such as normal population growth or diversion from other travel modes were not accounted for in the analysis. Approximately $1,095,300 (1987 dollars) were spent on the additional feeder bus service during the project.

New or Expanded Bus Service

Improvements in bus service during construction projects have involved the following actions:

1. Introducing new express bus service,

2. Expanding existing express bus service,

3. Increasing feeder service to commuter rail lines and rapid transit systems,

4. Adding buses to existing routes to maintain or decrease service headways, and

5. Placing back-up buses on-call in case of delays or breakdowns.

Table 4.6 summarizes the cost and effectiveness data of improving bus service for projects where data were available. Little increase in ridership was observed at the projects in Boston, Syracuse, and Detroit. In Seattle, a 10 percent increase in ridership was reported, but specific cost and ridership figures were not available. A modest increase in ridership was forecast for the project in Hartford. Pittsburgh and Milwaukee, in contrast, saw substantial increases in bus usage during construction.

Additional buses have been used to increase feeder service to commuter rail line and rapid transit stops in order to make rail service more attractive to drivers. This has generally been done in conjunction with other rail service improvements, so the effects of the feeder service improvements themselves are not known. Increasing bus service and placing buses on call are methods of maintaining normal or near normal service levels during construction, even though congestion and trip times through the construction zone may increase.

High-Occupancy Vehicle Lanes on Freeways and Alternative Routes

Three of the projects reviewed have implemented or are considering implementation of HOV lanes on either the freeway or alternative routes during construction. As part of the construction of I-81 in Syracuse, an HOV lane for buses and carpools with three or more persons was established on an alternative route adjacent to I-81. The lane provided a faster travel time into the downtown area than the freeway or other alternative routes. Officials spent approximately $110,000 for signing and other

TABLE 4.6. SUMMARY OF COST AND EFFECTIVENESS OF EXPRESS BUS SERVICE

	Costs[a]	Estimated Increase in Ridership (person-trips per day)	Cost per Trip
Boston	$1,165,300	-147	---[b]
Hartford	$2,882,700	330	$8.73[c]
Pittsburgh	$3,663,300	1,467	$4.99[d]
Seattle	N/A	N/A	N/A
Philadelphia	N/A	N/A	N/A
Milwaukee	$180,000	1100	$1.56[e]
Syracuse	$81,100	N/A	$12.28[f]
Detroit	N/A	N/A	N/A

[a] Costs are updated to 1987 dollars.

[b] A slight decrease in ridership was observed. Hence, a cost per trip measure is meaningless here.

[c] Expected costs assuming operations over a 4-yr period.

[d] Operated over a 2-yr period.

[e] Operated over a 5-mo period.

[f] Operated over a 4.5-mo period.

provisions for the lane. It was reported that usage of the lane was such that costs averaged $1.51 per car (1987 dollars). Specific benefits in terms of travel time reductions were not documented.

In Minneapolis, an interim HOV lane was built within the existing right-of-way as part of the construction of US 12 into I-394. The interim HOV lane, termed the "sane lane" for publicity purposes, served several objectives. Not only did it provide additional route capacity, but it also introduced and acclimated motorists to the use of the permanent HOV lane. An analysis of the first year of operation of the interim HOV lane showed that 2,000 vpd were attracted to it from the construction zone as well as from other routes in the corridor. Traffic allowed to use the HOV lane included buses, vanpools, and carpools with two or more persons. The lane was assumed to have a four-year service life (during construction) and an annualized cost of about $1,730,000, or about $3.46 per vehicle trip. The lane allowed vanpools and carpools to reduce their travel time by an average of 8 min while busses were able to reduce their travel time by an average of 15 min. The annualized benefits of the lane (in terms of operating costs and travel time savings to vehicles in both the HOV and mixed flow lanes) were computed to exceed $1,970,000, for a benefit-cost ratio of 1.1:1 (9).

The I-91 project in Hartford will add HOV lanes to the freeway. The task force for the project recommended that sections of the HOV lane be opened during construction as they are completed, provided that suitable beginning and ending points can be found. No cost or usage data are available at this time.

Improvements in Commuter Park-and-Ride Lots

An important part of transit and ridesharing improvements during construction has been the initiation and expansion of park-and-ride lots for public transit and other HOV users. These improvements are often necessary if increased HOV use is to be realized. Table 4.7 illustrates those projects that have initiated or expanded park-and-ride lots during construction. Where available, cost and parking space data are also provided. Methods of obtaining the right-of-way for the lots vary, including:

1. Use of land already owned by the highway agency,
2. The purchase of the land from its owner,
3. Leasing the land from its owner on a short-term or long-term basis, and
4. Agreements with merchants to allow commuters to use shopping center parking lots.

The costs of a park-and-ride lot vary depending on how it is obtained as well as on the improvements made and/or the amount of security provided. Experiences in Pittsburgh and Boston show that the key to the successful development and implementation of park-and-ride lots during construction is the flexibility to add or delete

TABLE 4.7. COST DATA FOR PARK-AND-RIDE LOTS

	Costs[a]	Increased Lot Capacity (parking spaces)	Cost per Parking Space[a]
Boston	$1,079,300	1600	$675
Minneapolis	N/A	N/A	N/A
Hartford	$214,500	600	$357
Miami	$1,640,000[b]	N/A	N/A
Chicago	N/A	N/A	N/A
Pittsburgh	$131,000	917	$143
Philadelphia	N/A	N/A	N/A
Syracuse	N/A	N/A	N/A

N/A Data Not Available

[a] Costs are updated to 1987 dollars

[b] Estimated capital and annual operating costs for four years

capacity or even discontinue those lots that are not used. Consequently, temporary measures such as leasing land or obtaining permission to use existing shopping center parking space would be quite appropriate, and allow the flexibility needed to update and modify those services.

New or Expanded Ridesharing Programs

An important action at many freeway construction projects has been the introduction or expansion of ridesharing programs (both vanpools and carpools). Actions have included expanded commuter matching programs and public information campaigns to promote the service. These promotions can be developed around marketing efforts to get commuters to call or write in to obtain information and to register, or they can be based around large employers in the area. The employers may provide additional incentives for ridesharing such as providing parking facilities or even vans for the programs. The success of ridesharing efforts is dependent upon the other HOV actions utilized. For example, the establishment of HOV lanes and ramps that provide travel time savings to ridesharing commuters will likely affect the success of a ridesharing campaign. Likewise, establishing appropriate park-and-ride lot locations will influence ridership.

Table 4.8 summarizes the available cost and effectiveness data for ridesharing programs in Pittsburgh, Boston, Syracuse, and Hartford. The efforts in Pittsburgh and Boston were primarily vanpool promotion programs, whereas the efforts in Syracuse and Hartford were directed at carpooling.

Summary

A wide range of actions have been utilized at construction projects in an attempt to divert vehicle-trips from the freeway construction zone to public transit and other HOV modes. In some instances, moderate increases in usage have been achieved (Minneapolis, Philadelphia, Pittsburgh). Overall, however, diversion to transit has been meager. In general, expansions of existing transit systems have been more successful than initiating new systems. Increases in ridership that do occur appear to be related more to the magnitude of travel time or cost savings that the HOV modes provide rather than to the amount of money spent on promotions or improvements. In Pittsburgh, the commuter train was heavily promoted but lightly used because it provided little travel time or cost savings over the automobile. In Boston, operating conditions on I-93 during construction were maintained near or at preconstruction levels. Again, there was little incentive to divert to alternative modes, and only modest increases in transit ridership were experienced during construction. In contrast, HOV ramps installed in Pittsburgh allowed vanpools, carpools and express buses to bypass congestion on the expressway and save about 8 min per trip, and usage of these modes was more substantial. The interim HOV lane in Minneapolis provided an 8 to 15 min travel time savings to commuters and has been utilized fairly heavily during construction.

TABLE 4.8. SUMMARY OF COST AND EFFECTIVENESS OF RIDESHARING PROGRAMS

	Costs[a]	Estimated Increase in Ridership (person-trips per day)	Cost per Trip[a]
Boston	$191,500	140	$2.74[b]
Minneapolis	N/A	N/A	N/A
Hartford	$91,000	N/A	N/A
Miami	N/A	N/A	N/A
Pittsburgh	$72,750	758	$0.19[b]
Seattle	N/A	N/A	N/A
Philadelphia	N/A	N/A	N/A
Syracuse	$6,650	N/A	N/A
Detroit	N/A	N/A	N/A

[a] Costs are updated to 1987 dollars

[b] Operated over a 2-yr period

N/A Not Available

Since it is difficult to accurately predict travel impacts and shifts in travel patterns during construction, it appears wise to avoid new capital-intensive systems unless those systems are part of the long-range plans for the corridor. In Boston, a wide range of improvements was implemented but with the flexibility to discontinue lightly used services. The approach taken by planners for the I-91 construction project in Hartford has been to plan for possible implementation of commuter rail service if conditions develop that would make it worthwhile. Such an approach might have similar advantages for future projects elsewhere.

Experiences to date suggest that a construction project by itself is unlikely to cause large numbers of motorists to change long-held travel habits regarding their choice of travel mode. However, a major construction project could be an ideal time to implement transit and other ridesharing improvements that are part of the long-term traffic management plan for the corridor. The delays during construction may provide the necessary additional incentive to prompt motorists considering ridesharing to change modes. Carpool/vanpool hotlines or express bus service to be initiated after an HOV lane is built, for example, could be implemented during construction to get commuters used to the idea of ridesharing. The approach used in Minneapolis was to provide an interim HOV lane during construction to build a market and acclimate motorists for the HOV lanes that will be part of I-394 after it is completed. Similarly, in Miami, the Florida Department of Transportation coordinated the start of commuter rail service between West Palm Beach and Miami to coincide with the start of construction activities on I-95 in the same corridor. In both cases, the construction project was seen as an opportunity to provide added incentive to use transit and other HOV modes.

5. PUBLIC INFORMATION PROGRAMS FOR FREEWAY CONSTRUCTION PROJECTS

Public information efforts have been an essential component of traffic management plans for freeway construction projects. These efforts have been necessary for (1) increasing public knowledge and acceptance of the project and the inconveniences that it may cause, and (2) promoting the use of alternative routes and modes to reduce congestion on the freeway during construction.

Although the level of effort has varied, the basic steps in developing the public information programs have been similar. First, the various audiences affected by construction are identified. Next, the needs of each audience are specified in terms of the type and amount of information required. Then, methods of disseminating that information are selected and implemented. Finally, the effectiveness of the methods is monitored, and adjustments in information and/or method of dissemination are made accordingly.

Previous construction projects have targeted one or more of three basic audiences in their public information programs:

1. Motorists using the freeway,
2. Residents living adjacent to the freeway, and
3. Nearby businesses.

Individuals may belong to more than one of these categories. In some cases, further breakdowns of the first category have been made. For example, officials in Philadelphia identified two important groups of users of I-76, local commuters and longer-distance, through drivers. The public information campaign was designed to encourage local commuters to use alternative routes and modes during construction, while encouraging through drivers to remain on the facility. In Pittsburgh, local commuters were targeted in an attempt to persuade them to use public transit, particularly the commuter train, during I-376 construction.

Public information efforts have also been important in keeping residents apprised of project schedules, ramp closings, and other events pertinent to their day-to-day lives. In addition, these information campaigns have served to reduce resident complaints and promote their acceptance of the inconveniences that may be caused by construction.

Nearby businesses have been targeted in some of the public information campaigns promoting ridesharing or public transit alternatives during construction. In Miami, businesses who employ large numbers of I-95 commuters are being encouraged to support variable work hours as a means of redistributing peak-period traffic during construction.

Public Information Tools

Several tools have been used to disseminate information to the public. The tools used depend on both the intended audience and the amount of information. As an overview, the following categories of public information tools have been utilized during the construction projects reviewed in this report:

1. Traditional tools,
2. Special publications,
3. Toll-free hotlines,
4. Highway advisory radio,
5. Special freeway signing, and
6. Ombudsman.

Traditional Public Information Tools

Traditional public information tools encompass the following:

1. Press conferences,
2. Media events,
3. Press tours,
4. Press kits,
5. News releases,
6. Public service announcements,
7. Paid advertising,
8. Interviews, and
9. Public meetings and presentations.

These items are in addition to the media coverage that typically occurs immediately prior to and at the beginning of a construction project. Items 1 through 8 are methods of providing general information to a large audience through newspaper, radio, and television. In contrast, public meetings and presentations can provide more specialized information to a smaller group of people with particular interests (for example, a neighborhood special interest group). Except for paid advertising, these tools are relatively inexpensive. However, in many cases one does not have control over what information is provided to the public, since media personnel interpret and edit coverage to fit their own time and space limitations.

Special Publications

Special publications developed for past construction projects have included the following:

1. Posters,

2. Pamphlets,

3. Newsletters,

4. Maps, and

5. Special mailings

To date, all of these techniques have been effective at (1) informing the public of the presence of construction and of changes in condition that may occur as work progresses, and (2) promoting commuter use of alternative routes and modes during construction.

Toll-Free Hotlines

Toll-free hotlines were established at a number of construction projects, including those in Seattle, Boston, Pittsburgh, Philadelphia, Detroit, and Minneapolis. A hotline provides a way for the public to obtain up-to-date information concerning traffic conditions and construction schedules. A hotline also provides a way for citizens to voice their concerns and complaints about a project. In some cases, the hotlines were operated manually through information centers. In others, recorded messages, updated periodically, provided pertinent information to callers. In Minneapolis, phone personnel were replaced with recorded messages soon after the beginning of the I-394 project in an attempt to reduce the cost of the hotline.

Highway Advisory Radio

Providing drivers with real-time information concerning travel conditions on the freeway under construction as well as on alternative routes in the corridor is another important aspect of a successful public information program (1). Highway advisory radio

(HAR) has been used at construction projects in Seattle and Chicago, and is proposed for the I-95 construction in Miami. The ability of HAR to influence driver travel patterns has been well documented, and guidelines regarding the operation of HAR are available (41).

Special Signing

Special informational signing has been used at virtually all construction projects to date. This category includes (1) special signing designating alternative routes, (2) large billboard advertisements to encourage ridesharing during construction, and (3) changeable message signs to keep motorist informed of lane closures and changes in traffic control during the project.

Ombudsman

An ombudsman was employed during the construction of US-10 in Detroit. The ombudsman worked with community organizations as well as individuals to resolve home or business problems related to dust, noise, cracked walls or other events caused (or perceived to be caused) by the construction.

Success of Public Information Campaigns During Construction

Although it is difficult to quantify the benefits associated with a sound public information program, it is nevertheless vital to the successful completion of a major freeway construction project and helps prevent negative public reaction. In addition, such a program is necessary to assure the public that (1) the work is necessary for the long-term good, and (2) the agencies involved are doing their best to complete the project with the least inconvenience possible to motorists, residents, and businesses. Three important elements of the programs have been the efforts to (1) keep the public informed of the conditions through the construction zone and of the availability of travel alternatives, (2) coordinate the actions of all public agencies directly involved in the project, and (3) maintain communications with major public and private groups affected by the project.

General indications of the costs and effectiveness of the public information programs at several projects are shown in Table 5.1. As can be seen, the efforts to inform the public appear to have worked; public knowledge and acceptance of the projects has been very high, near 90% in most instances. Perhaps a better indication of the impact of the programs has been (1) the lack of congestion at the beginning of most of the projects because drivers heeded the responsible agency's advice to avoid the construction zone, and (2) the generally positive public attitude about the projects and the agencies involved.

TABLE 5.1. SUMMARY OF COST AND EFFECTIVENESS OF PUBLIC INFORMATION PROGRAMS

	Costs (1987 Dollars)	% of Public Aware of and In Agreement with Construction Project
Boston	$174,000	95%
Seattle	$78,000	89%
Minneapolis	$170,000	90%

6. SUMMARY AND CONCLUSIONS

This report synthesizes the traffic management experiences from 12 completed or ongoing urban freeway construction projects nationwide. The purpose of the synthesis has been to (1) identify the common elements that contribute to the success of corridor traffic management plans for construction projects, and (2) provide insights regarding the project, freeway, and urban area characteristics that influence the effectiveness of the traffic management plan during construction.

Because the impacts of a major construction project may extend beyond the freeway being reconstructed to alternative routes and modes, a corridor-wide traffic management plan may be needed. A corridor-wide plan consists of three components: (1) a traffic control plan for the freeway under construction, (2) TSM-type improvements to accommodate traffic diverted to alternative routes and modes in the corridor, and (3) a public information program for nearby residents, businesses, and motorists using the facility. The traffic control plan for a project and the improvements to alternative routes and modes necessary for that project are interdependent. The greater the reduction in capacity on the freeway during construction, the more traffic that will likely divert, and the greater the need for improvements to minimize the adverse impacts of traffic diverted to alternative routes and modes in the corridor.

Three basic traffic control plans have been used during construction: (1) narrow lanes and/or reduced or eliminated shoulders, (2) freeway lane closures, and (3) total freeway closures. Regardless of the traffic control plan selected, it is desirable to optimize the capacity of the freeway. Several techniques for maximizing the capacity of the freeway construction zone have been employed, including portable concrete barriers, paddle screens, ramp closures or restrictions, shoulder conversions to temporary travel lanes, reversible lanes, and incident management techniques. Experiences to date indicate that each of these techniques can provide benefits within the construction zone.

Data collected at the projects reviewed in this report indicate that the most common change in travel patterns during freeway construction is the diversion of traffic to alternative routes. Consequently, the improvements on alternative routes in the corridor have been important for maintaining acceptable levels of service on the routes. Improvements on alternative routes fall into three basic categories: (1) traffic signal improvements, (2) other intersection improvements, and (3) other roadway improvements. Within each category, several actions are possible, ranging from those that are temporary and can be made at low cost to those that are more permanent and capital-intensive. The effectiveness of each action depends upon both existing site-specific conditions and the amount of diversion that is anticipated. The lower-cost improvements (including signal timing changes, temporary signals, left-turn and parking prohibitions, pavement repairs, and lane restriping) should be given first consideration. If these actions are insufficient, then more costly and permanent improvements (new signal equipment, channelization, or roadway widening) should be considered. Cost-effectiveness evaluations for the more permanent improvements should account for benefits and costs over the life of the improvement, including those incurred after the completion of the construction project.

Diversion of commuting trips to public transit or ridesharing has been heavily emphasized at some of the projects. However, experiences to date suggest that construction projects are unlikely to change motorists' long-held mode choice patterns. Even with costly improvements and promotions, it has been difficult to increase transit ridership significantly during construction. Expanding existing transit or HOV services has been more cost-effective than initiating totally new services. Increased HOV usage is dependent upon the amount of time or cost savings provided to individuals relative to their normal automobile trip. It appears that a substantial travel time advantage for HOVs is required to divert significant numbers of motorists to HOV modes during construction. Low-cost actions, such as restricting ramps to HOVs only, that yield travel time savings to HOV users have proven to be cost-effective.

An important lesson learned from the projects reviewed in this report is that it is difficult to predict how motorists will change their travel patterns in response to a construction project and, consequently, that there should be room for considerable flexibility in the implementation of a corridor traffic management plan. Certain TSM techniques offer flexibility and may be implemented with little risk. For example, signal timing changes, turn prohibitions, and parking restrictions on alternative routes are relatively inexpensive and can be modified at low cost in response to changing traffic conditions. However, more capital-intensive improvements, such as intersection channelization, or capital improvements to public transit systems are more permanent. A strategy used at several projects has been to accelerate the implementation of improvements already scheduled for alternative routes so that they are in place before construction begins. In a similar fashion, implementation of some improvements can be put on hold until conditions during construction are evaluated and the need for the actions verified. A final alternative is to implement actions on a temporary basis and subsequently to reduce or eliminate those actions that are found to be unnecessary. For example, park-and-ride lots may be leased rather than purchased, and contractual arrangements for expanding transit service may include provisions to discontinue lightly used routes. Incorporating as much flexibility as possible facilitates modifications to the traffic management plan during construction, and thereby enables the plan to be more responsive to changes in traffic conditions.

Each construction project is unique. Traffic management techniques that are effective at one project may not work at another. Therefore, caution must be exercised in applying the experiences from the projects reviewed in this report. Throughout the report, both the similarities between projects and the reasons for differences have been highlighted. The data presented indicates the order of magnitude of the costs and effectiveness of traffic management techniques that have been employed nationwide. Certain techniques, particularly the low-cost improvements on alternative routes have consistently proven cost-effective. Conversely, the cost effectiveness of other techniques, particularly improvements on alternative modes, has varied depending on location. Continued documentation of experiences during major urban freeway construction is needed in order to develop a clearer understanding of the interactions between the components of a corridor traffic management plan and the site-specific characteristics that influence the cost-effectiveness of alternative traffic management techniques.

REFERENCES

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

2. Corridor Traffic Management for Major Highway Reconstruction: A Compilation of Case Studies. Washington, DC: Federal Highway Administration, 1986.

3. Transportation Management for Corridors and Activity Centers: Opportunities and Experiences. Report No. DOT-I-86-21. Washington, DC: Federal Highway Administration, 1986.

4. "Traffic Reroute." Civil Engineering, Vol. 54, No. 7, 1984, pp. 37-39.

5. Steffens, W.T., Weinstock, S., and Sullivan, M.E. Corridor Transportation Management for Highway Reconstruction: Southeast Expressway, Massachusetts 1984-1985. Report No. DOT-I-86-35. Boston, MA: Massachusetts Department of Public Works, 1986.

6. Meyer, M.D. "Reconstructing Major Transportation Facilities: The Case of Boston's Southeast Expressway." Transportation Research Record 1021, 1985, pp. 1-9.

7. Eyler, D.R., Beltt, C.Z., and Borson, R.D. "The I-394 Interim HOV Lane: A Valuable Construction Zone Traffic Management System." Compendium of Technical Papers. 56th Annual Meeting of the Institute of Transportation Engineers, 1986.

8. Strgar-Roscoe-Fausch, Inc. Transportation Systems Management Plan: Interstate-394. Final Report. Minneapolis, MN: Minnesota Department of Transportation, 1986.

9. Strgar-Roscoe-Fausch, Inc. I-394 Interim HOV Lane: A Case Study. Phase I Report. Minneapolis, MN: Minnesota Department of Transportation, 1987.

10. Jain, R. "Traffic Management During Reconstruction of I-91 in Connecticut." ITE Journal, Vol. 57, No. 10, October 1987, pp. 29-32.

11. Potential Alternative Transportation Strategies During Reconstruction of I-91 from North of Hartford to Massachusetts State Line. Final Report. Hartford, CN: I-91 Corridor Management Plan Task Force, July 1984.

12. Frederic R. Harris, Inc. I-95 Reconstruction System Maintenance of Traffic Program. Fort Lauderdale, FL: Florida Department of Transportation, 1988.

13. Kuo, N.M., and Mounce, J.M. "Operational and Safety Impacts on Freeway Traffic of High-Occupancy Vehicle Lane Construction in a Median." Transportation Research Record 1035, 1985, pp. 58-65.

14. Ziejewski, S.C. "Traffic Planning for Edens Reconstruction Project." Journal of Transportation Engineering, Vol. 109, No. 1, 1983, pp. 159-171.

15. Yamanaka, H.M. "Social and Environmental Impacts: Edens Project." Journal of Transportation Engineering, Vol. 109, No. 5, 1983, pp. 721-732.

16. Wehner, R.C. "Eisenhower Expressway Rehabilitation versus Edens Expressway Reconstruction: A Comparative Analysis." Schaumberg, IL: Illinois Department of Transportation, Division of Highways, District 1.

17. McLean, C.B. "The Edens Reconstruction Project." Transportation Research News, No. 94, 1981, pp. 9-13.

18. Anderson, R.B., Hendrickson, C.T., Janson, B., Kundrat, D.F., and Taylor, L. Robert. Study of Alternative Transportation Strategies During Reconstruction of the Parkway East, I-376, Pittsburgh, Pennsylvania. Final Report. Report No. 81-118. Monroeville, PA: GAI Consultants, Inc. and Pittsburgh, PA: Carnegie-Mellon University, 1983.

19. Hendrickson, C.T., Carrier, R.E., Dubyak, T.J., and Anderson, R.B. "Travel Responses to Reconstruction of Parkway East (I-376) in Pittsburgh." Transportation Research Record 890, 1982, pp. 33-39.

20. "Reconstruction Demands Traffic Control Savvy." Engineering News Record, September 19, 1985, pp. 52-53.

21. The Flexibility Document. Washington, DC: Federal Highway Administration, 1986.

22. Eichorn, W., and Morasco, L.M. "Philadelphia, Schuylkill Expressway." Transportation Management for Major Highway Reconstruction. Special Report 212. Washington, DC: Transportation Research Board, 1987.

23. Greene, J.L., and Rodgers, R.M. "Traffic Management Plan for the Reconstruction of the Schuylkill Expressway." Compendium of Technical Papers. 54th Annual Meeting of the Institute of Transportation Engineers, 1984.

24. "Space, Deadlines Tight on Highway Reconstruction." Engineering News Record, October 3, 1985, p. 34.

25. Mieras, J.M. "Traffic Impacts of Bridge Resurfacing on Northbound Interstate 5 Through Seattle." ITE Journal, Vol. 56, No. 3, March 1986, pp. 29-31.

26. Bockstruck, R.E. "Seattle Ship Channel Bridge." Transportation Management for Major Highway Reconstruction. Special Report 212. Washington DC: Transportation Research Board, 1987.

27. Sonntag, R.C. "Traffic Management for Major Freeway Reconstruction: I-94 Menomee Valley Bridge, Milwaukee," Compendium of Technical Papers. 58th Annual Meeting of the Institute of Transportation Engineers, 1984.

28. Simberg, R.N. "Syracuse, Interstate 81." Transportation Management for Major Highway Reconstruction. Special Report 212. Washington, DC: Transportation Research Board, 1987.

29. Neveu, A.J., and Maynus, L. "How to Manage Traffic During Highway Reconstruction." Albany, NY: New York State Department of Transportation, 1985.

30. Scott, P. "The New Lodge." Corridor Traffic Management for Major Highway Reconstruction: A Compilation of Case Studies. Washington, DC: Federal Highway Administration, 1986.

31. Tadi, R.R., Kobran, M.F., and Bremer, R.J. "Impact of the Lodge Freeway Reconstruction Closure on Surface Streets Within Detroit." ITE Journal. Vol. 58, No. 9, September 1988, pp. 27-32.

32. Chui, M. and McFarland, W. The Value of Travel Time: New Estimates Developed Using a Speed-Choice Model. Report No. FHWA/TX-86/33+396-2F. College Station, TX: Texas Transportation Institute, May 1986.

33. McCasland, W.R. The Use of Freeway Shoulders to Increase Capacity. Research Report No. FHWA/TX-78-210-2. College Station, TX: Texas Transportation Institute, September 1978.

34. Urbanik, T. and Bonilla, C.R. Safety and Operational Evaluation of Shoulders on Urban Freeways. Report No. FHWA/TX-87/32+395-1. College Station, TX: Texas Transportation Institute, February 1987.

35. Urbanik, T. and Bonilla, C. "California Experience with Inside Shoulder Removal." Transportation Research Record 1122, 1987, pp. 37-46.

36. "Road Building Demands Time." North Central Expressions, Vol. 1, No. 3, September 1988. Newsletter published by the Texas State Department of Highways and Public Transportation, Dallas, TX.

37. North Carolina Department of Transportation and the Institute of Transportation Research and Education. "North Carolina's Traffic Signal Management Program for Energy Conservation." ITE Journal, Vol. 57, No. 12, 1987, pp. 35-38.

38. Batchelder, J.H., Golenburg, M., Howard, J.A., and Levinson, H.S. Simplified Procedures for Evaluating Low-Cost TSM Projects User's Manual. National Cooperative Highway Research Program Report 263. Washington, DC: Transportation Research Board, October 1983.

39. ESTOP Manual for Calculating Traffic Operations Benefits. Evanston, IL: Barton-Aschman Associates, Inc., September 1981.

40. A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements. Washington, DC: American Association of State Highway and Transportation Officials, 1977.

41. Dudek, C. and Huchingson, D. Manual on Real-Time Motorist Information Displays. Report No. FHWA-IP-86-16. Bryan, TX: Dudek & Associates, August 1986.

APPENDIX A:
SUMMARIES OF MAJOR FREEWAY CONSTRUCTION PROJECTS

I-94, Edens Expressway, Chicago

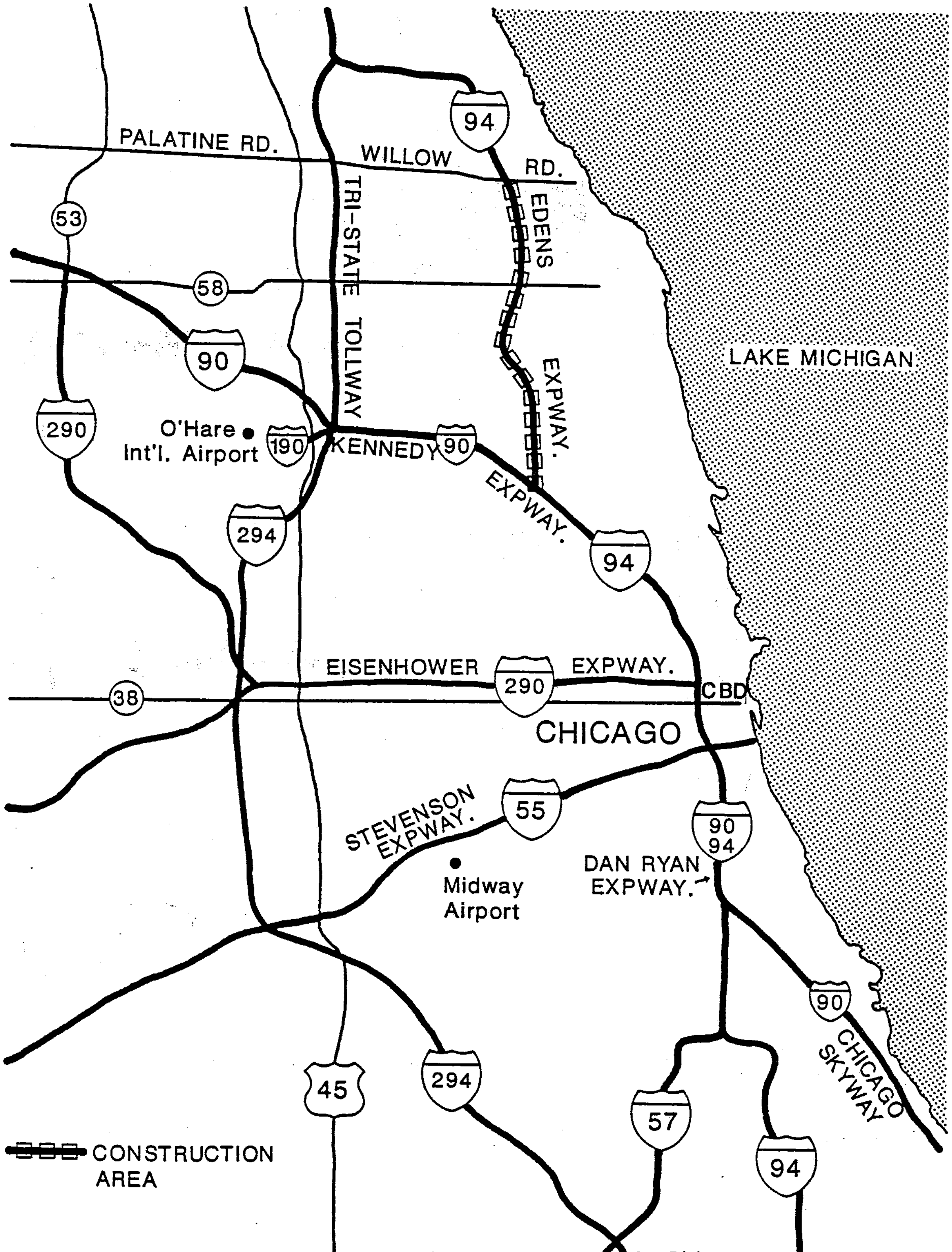
The Edens Expressway, opened to traffic in 1951, is a six-lane freeway which serves as the principal arterial through the north shore suburbs of Chicago. Figure A-1 illustrates this freeway corridor. The ADT on the expressway before construction ranged from 57,000 vpd at the Lake-Cook county line to 135,000 vpd at the southern terminus with the Kennedy Expressway (I-90). A three-year construction project was undertaken by the Illinois Department of Transportation (IDOT) on a 15 mi segment of the Expressway to (1) remove the existing pavement and replace it with a 10-in reinforced concrete pavement, (2) reconstruct the shoulders, (3) reconstruct the drainage system, (4) widen and redeck all bridges, (5) replace the median guardrail with a concrete median barrier, (6) lengthen the ramp speed change lanes, and (7) modernize signing, lighting, and traffic surveillance equipment. The project was performed during the construction seasons of 1978 - 1980. Several articles have documented the project (14-17).

The work was performed under six contracts. Each contract stipulated a completion date and included an incentive/disincentive clause. The clause assessed the contractor a liquidated damage of $15,000 for each day late. The incentive had two levels: the contractor would be paid $7,500 for each day a contract was completed early, and an additional $7,500 per day if all six contracts were completed early (the same contractor apparently had all six contracts). However, incentives would be paid only if a contract was completed at least 31 days before the stipulated completion date.

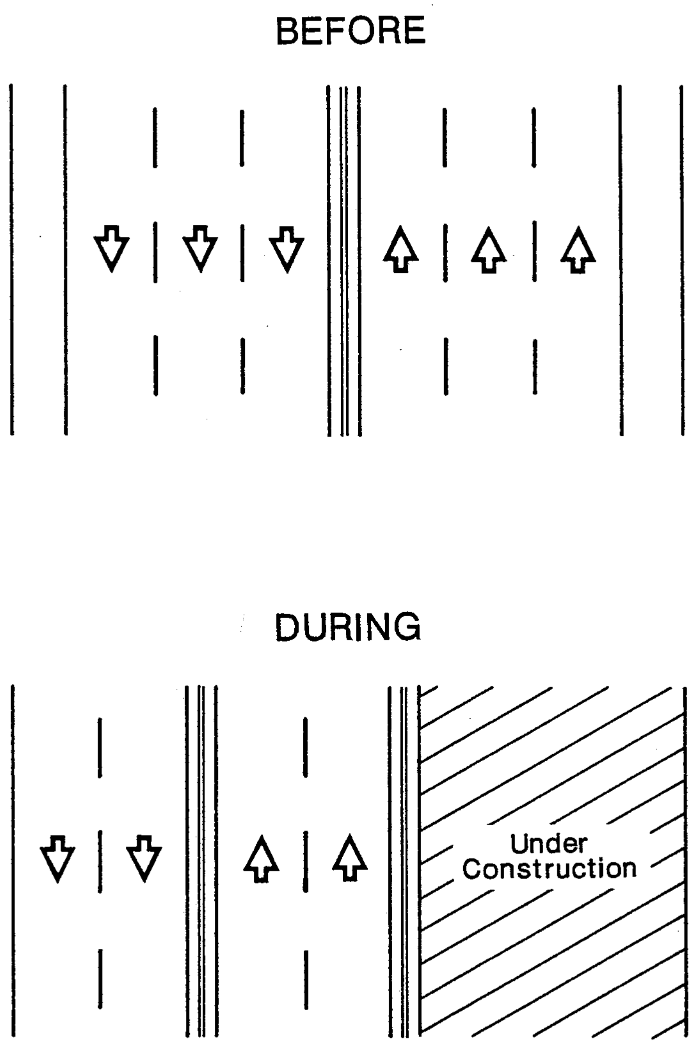
A variety of traffic management strategies, ranging from a total freeway closure to lane closures only in active work areas were considered during project planning. The option selected was to close one directional roadway of the Expressway at a time and to maintain four-lane, two-way traffic on the other roadway. This was accomplished by upgrading the right shoulder to serve as a temporary lane. PCBs were used to separate the two-way traffic. A schematic drawing of the TCP strategy used on the Edens Expressway is shown in Figure A-2.

The traffic management plan during construction had three stages. In the first stage, the southbound right lane was closed, while the southbound right shoulder was upgraded to handle traffic. In the second stage, four- lane, two-way traffic was maintained in the southbound lanes and upgraded shoulder, while the northbound direction was closed to construct the main lanes, median, and shoulders . In the third stage, four-lane two-way traffic was maintained in the new northbound lanes and right shoulder, while the southbound lanes were closed for construction.

A 35 mph speed limit was established during four-lane, two-way operation due to the reduced lane widths, restricted lateral clearances to the median barrier, proximity of construction operations, low-speed temporary ramp connections, and frequent changes in ramp closures.



Fiqure A-1. I-94, Edens Expressway, in Chicago.



Fiqure A-2. Schematic of TCP Strategy for I-94 Construction.

The Edens Expressway was constructed before the FHWA authorized the use of federal funds for impact mitigation actions off the Interstate. Therefore, the IDOT was not able to fund improvements on alternative routes and in HOV services. The IDOT did provide project information to the Regional Transportation Authority which increased transit and park-and-ride lot capacity in the corridor. Signing on the Expressway encouraged carpool and transit usage. The IDOT also worked with municipal and county highway and public works agencies to coordinate highway maintenance schedules on alternative routes.

Traffic management and monitoring during construction were handled by the following three units with operational responsibility for the Chicago Metropolitan Area Expressway System: the Highway Communications Center, the Emergency Traffic Patrol, and the Traffic Systems Center.

The Highway Communications Center monitors and disseminates expressway congestion information and coordinates all traffic, maintenance, and construction operations, including the Emergency Traffic Patrol fleet. During the construction project, the Communications Center took several special actions: (1) a direct telephone line was installed to the prime contractor's office, (2) portable two-way radios were issued to the state construction engineers for the project, (3) live broadcasts about special activities or incidents were provided to the news media, (4) municipal enforcement agencies were notified 24 hours in advance of any ramp closures, and (5) a Highway Advisory Radio system was operated.

The Emergency Traffic Patrol travels the Chicago expressways to identify incidents and to initiate response actions. The normal patrol of one unit on the Edens Expressway was intensified during construction to two units off-peak and three units during peak periods. Also, a heavy duty tow truck was made available in addition to the one already in use.

The changes in traffic patterns during construction were monitored using data from the electronic surveillance system operated by the Traffic Systems Center. It took several weeks after the start of the project for traffic patterns to stabilize. The ADT on the Expressway decreased by approximately 30 percent during construction. Volumes during peak periods decreased by as much as 35 percent, with the highest levels of peak-period diversion occurring during the first several weeks of the project. Officials attributed 20 of the 30 percent decrease in ADT to diversion to the Tri-State Tollway, a parallel facility approximately 6 mi west of the Edens. The remainder of the decrease in traffic volumes was attributed to: (1) diversion to arterial streets, (2) diversion by long-haul truckers and interstate drivers to other freeways, (3) elimination or diversion of discretionary, non- work trips from the Edens, and (4) reduction in trips due to the energy crisis which began in April 1979. Transit ridership in the corridor increased during the first few days of the project but soon returned to preconstruction levels. No excessive deterioration in service quality on the alternative routes was noted during construction.

A comparison of Edens Expressway accident data before and during construction suggested that although the frequency of accidents on the Expressway was lower during construction, the accident rate was higher due to the lower traffic volumes on the Expressway during construction. In addition, the data indicated that both the percentage of accidents involving trucks and the percentage of accidents involving non-local drivers was higher during construction.

I-376, Penn-Lincoln Parkway East, Pittsburgh

The Parkway East is the only major east-west freeway connecting the Pennsylvania Turnpike and eastern suburban communities with downtown Pittsburgh. Figure A-3 shows the Parkway East travel corridor. The facility is a four-lane freeway, including the 0.8-mi double-bore Squirrel Hill Tunnel. A total of 132,000 vpd entered the section being constructed. A $62 million construction project was undertaken on a 6.5-mi section of the Parkway during the 1981 and 1982 construction seasons (March through October). Work included (1) placement of an 8-in concrete pavement overlay, (2) rehabilitation of 21 bridges, (3) installation of new lighting and ventilation in the tunnel, and (4) installation of new signing and high mast lighting. Work was concentrated on the inbound (westbound) lanes in 1981 and on the outbound (eastbound) lanes in 1982.

The Parkway East was the first urban freeway construction project in which FHWA approved the use of Interstate funds to mitigate the off-system impacts of Interstate construction. Because of this innovation, 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 usage of the impact mitigation strategies. The findings of the study have been thoroughly documented in an extensive report and in several related articles (18-20).

It was recognized early in the planning process that the potential existed for severe traffic disruptions during construction. The basic TCP strategy selected for use during most of the project was to close both lanes of one directional roadway (inbound in 1981 and outbound in 1982) and to maintain two-lane, two-way traffic on the other directional roadway, as depicted in Figure A-4. The entrance ramps within the construction zone were closed and the entrance ramp nearest each end of the zone was restricted to HOV use only. Individual exit ramps within the zone were closed when directly affected by work activity.

The closure of one directional roadway of the freeway reduced the number of travel lanes from four to two, and the closure of entrance ramps restricted access. As a result, many motorists were forced to divert from the Parkway. The only alternative routes were arterial streets, many of which were congested even before the restrictions were imposed on the Parkway. Therefore, project planners brainstormed to identify people-moving strategies that had a reasonable chance of success. The strategies included:

1. Instituting a new commuter train that operated between Pittsburgh's eastern suburbs and central business district;

2. Contracting with a third-party vanpool coordinator to organize vanpooling in the eastern suburbs;

3. Contracting with the local transit authority to add several express bus routes in the corridor;

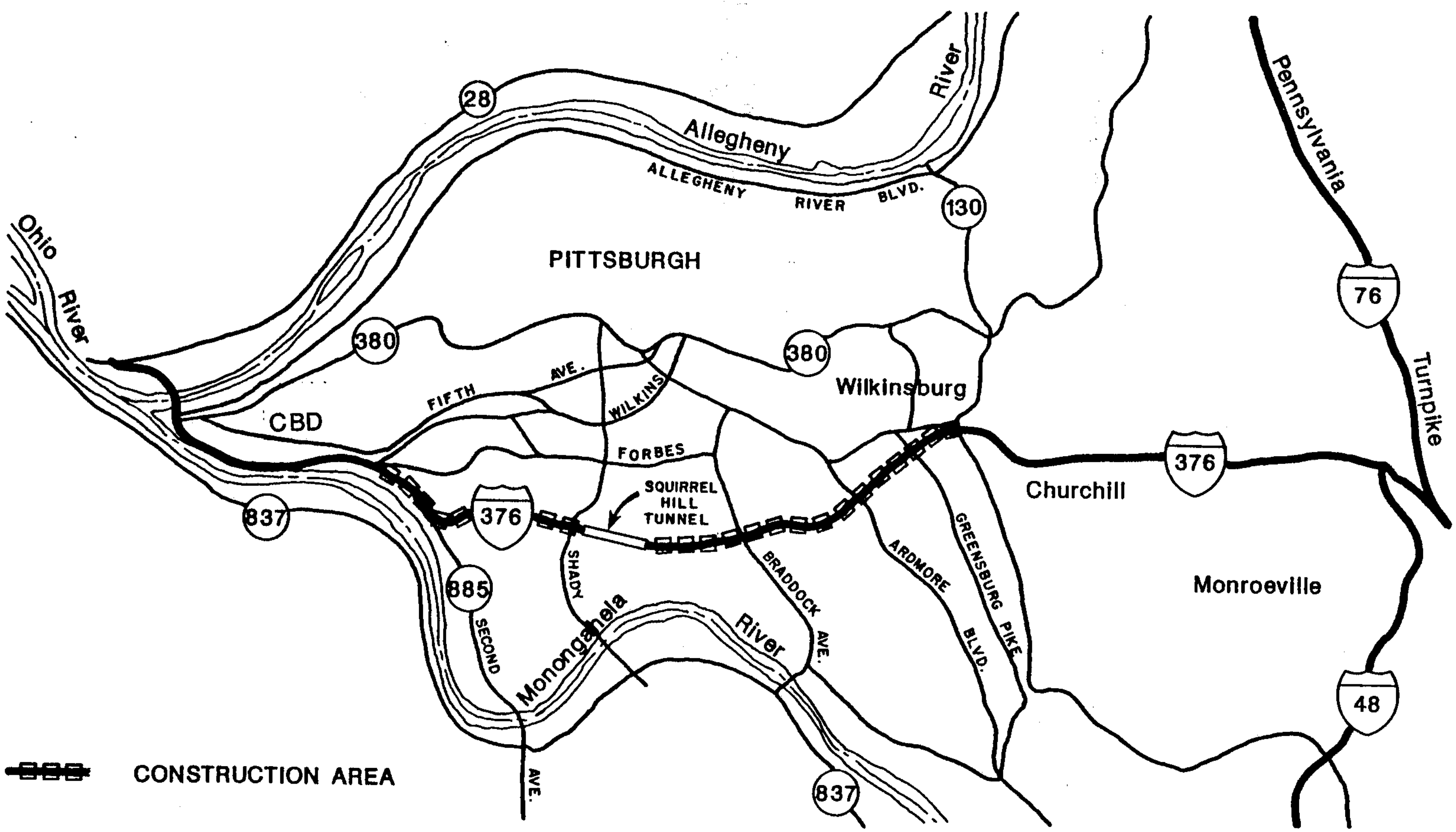
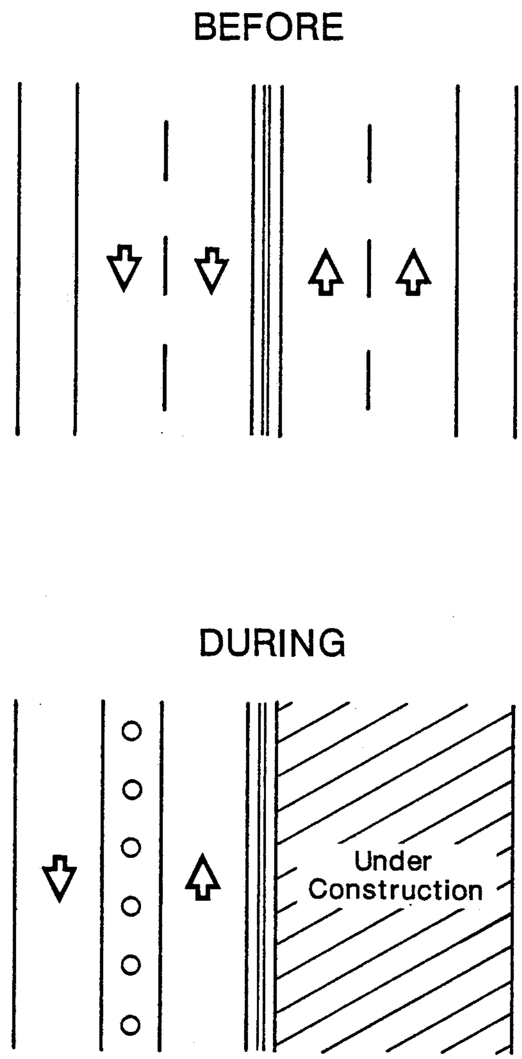


Figure A-3. I-376, Penn-Lincoln, Parkway East, in Pittsburgh.



Fiqure A-4. Schematic of TCP Strategy for I-376 Construction.

4. 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;

5. Restricting entrance ramps to the Parkway at both ends of the construction zone to HOVs; and

6. Making traffic operations improvements on several alternative routes in the corridor.

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

The Parkway East project was the first in which FHWA approved 90 percent Interstate matching funds for strategies, such as those described above, to mitigate the travel impacts off the Interstate. The initial approved cost for the alternative transportation strategies was more than $11 million, although only $4.8 million were actually expended.

In response to the traffic restrictions, the total volume of traffic entering the Parkway East construction zone decreased by 60 percent from 132,000 vpd before construction to 52,000 vpd during. The percentage reduction in volumes during morning and evening peaks was even greater. Through the Squirrel Hill Tunnel, for example, the morning peak hour volume dropped by almost 70 percent, from 3500 vph to 1100 vph in the peak direction. However, the counts along the complete screenline, which included all major highways in the corridor and which cut through the center of the construction zone, were only slightly less during construction than before. These counts, in conjunction with other data, indicated that the most common response by motorists was to continue to drive their automobiles 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 arterial streets closest to the Parkway accounted for more than 60 percent of the decrease in volume on the Parkway.

Average vehicle occupancy in the corridor changed very little during construction, remaining at approximately 1.4 persons per vehicle. However, average vehicle occupancy on the Parkway itself increased during construction from 1.4 to almost 1.7 persons per vehicle. These statistics, along with the screenline traffic counts, suggest that, overall, there was little diversion to HOV modes. However, carpools and vanpools apparently found the use of the Parkway advantageous because of the HOV-only ramps.

During the first construction season, average travel times on the Parkway increased by about 9 min (30 percent) inbound during the morning peak and 20 min (154 percent) outbound during the evening peak. Average travel times throughout the whole corridor increased by 16 percent inbound during the morning peak and by 57 percent outbound during the evening peak. Travelers accommodated these increases with departure times that averaged 20 min earlier during construction.

The effectiveness of the alternative transportation strategies varied. The new commuter train carried far fewer passengers than had been anticipated. Suburban community officials had predicted 2,800 to 7,600 riders per day. However, the actual average daily ridership which was about 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 weekday using the commuter train during the first construction season was estimated to represent a reduction of 200 weekday vehicle trips on the Parkway East.

Six new 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 1400 during the first season and 1500 during the second season which represented a diversion of about 500 weekday vehicle trips from the entire corridor and more than 300 weekday vehicle trips from the Parkway East.

The vanpool program operated 18 vanpools during the first season, representing more than 600 weekday passenger trips and the diversion of 165 weekday vehicle trips from the corridor and almost 100 weekday vehicle trips from the Parkway. During the second season, as many as 34 vanpools operated in the corridor.

The park-and-ride lots were coordinated with the express bus service and vanpool program. Initially, 12 existing parking lots were designated as new park-and-ride lots to supplement the 10 lots that had been in use before construction. Five of the twelve new lots were discontinued during the first construction season due to low usage.

The HOV-only 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 min.

In summary, despite a reduction in the number of lanes on the Parkway East from four to two, the negative impact on motorists was deemed small (19). Significant traffic diversion away from the Parkway did occur during the construction project; 60 percent fewer vehicles per day entered the Parkway construction zone. However, the total traffic on all routes in the corridor decreased only slightly. The most common motorist response to the construction was to change to alternative routes and to depart earlier. The ride-sharing options accounted for about 5 percent of the vehicles diverted from the Parkway during the peak period. Therefore, the improvements to alternative routes were deemed the most effective means of accommodating the traffic diverted from the construction zone.

I-10, Katy Freeway, Houston

The Katy Freeway is a major Interstate highway serving traffic from western Harris county to various parts of Houston. Figure A-5 illustrates this freeway corridor. The freeway cross section in this section varies from six lanes at the western end to eight lanes at the eastern end. As of 1982, traffic volumes on this section varied between 135,000 and 186,000 vpd. During 1983 and 1984, the Texas State Department of Highways and Public Transportation, (TSDHPT) in conjunction with the Houston-Harris County Metropolitan Transit Authority (METRO), initiated a construction project to rehabilitate the main lane pavement and to retrofit a barrier-separated reversible HOV lane in the median of a 5-mi section of the Katy Freeway (see Figure A-5). The HOV lane was the first section of a planned 70-mi network of HOV lanes on the freeways in the Houston area.

The project contract specified that the number of travel lanes available to traffic during peak periods would be the same as were available before construction began. Therefore, the project was accomplished through a complicated sequence of construction phases and steps within each phase. Travel lanes were narrowed to 10- or 11-ft, and shoulders were converted into travel lanes. Work areas were created in the median and on each directional roadway as needed, and traffic moved to other parts of the cross section. These work areas were separated from traffic by PCBs. Figure A-6 illustrates the basic TCP strategy used during construction. Temporary lane closures were allowed during off-peak periods to reposition the PCBs during phase changes and for other necessary work.

No actions were taken explicitly to improve traffic conditions on alternative routes or for HOVs during construction. Entrance ramps were closed as needed for construction purposes, but continuous frontage roads on each side of the freeway provided convenient routes to the next available ramp. Exit ramps were also closed as necessary for construction.

The potential impacts of the narrowed lanes and removal of shoulders were of interest to the TSDHPT and METRO. Consequently, traffic operations and safety were monitored through the construction zone during the project. Traffic speeds, volumes, and lane distributions were examined, as were accident rates. Overall, it appeared that construction had little or no effect on operations. Peak-period traffic volumes during construction were approximately 1750 vphpl. These observed volumes exceeded the theoretical capacity of 1680 vphpl, estimated using the 1965 Highway Capacity Manual (42) procedures for a basic freeway section with 10.5-ft lanes and no lateral clearance to an obstruction. No significant changes were found in average speeds or in lane distribution as a result of construction. Total accident rates before and during construction were compared, and significant increases were detected at a 95 percent confidence level. No detailed data regarding the characteristics of the accidents were published, however.

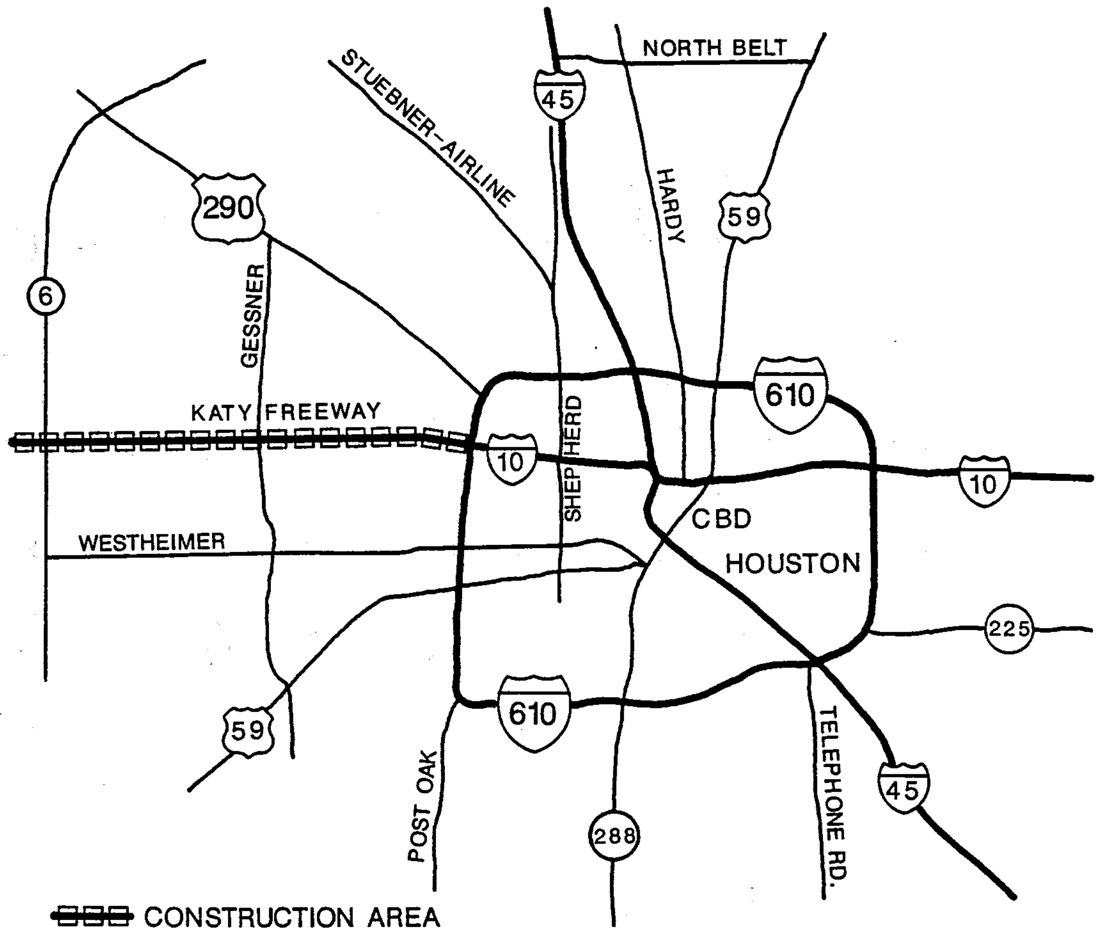


Figure A-5. I-10, Katy Freeway in Houston.

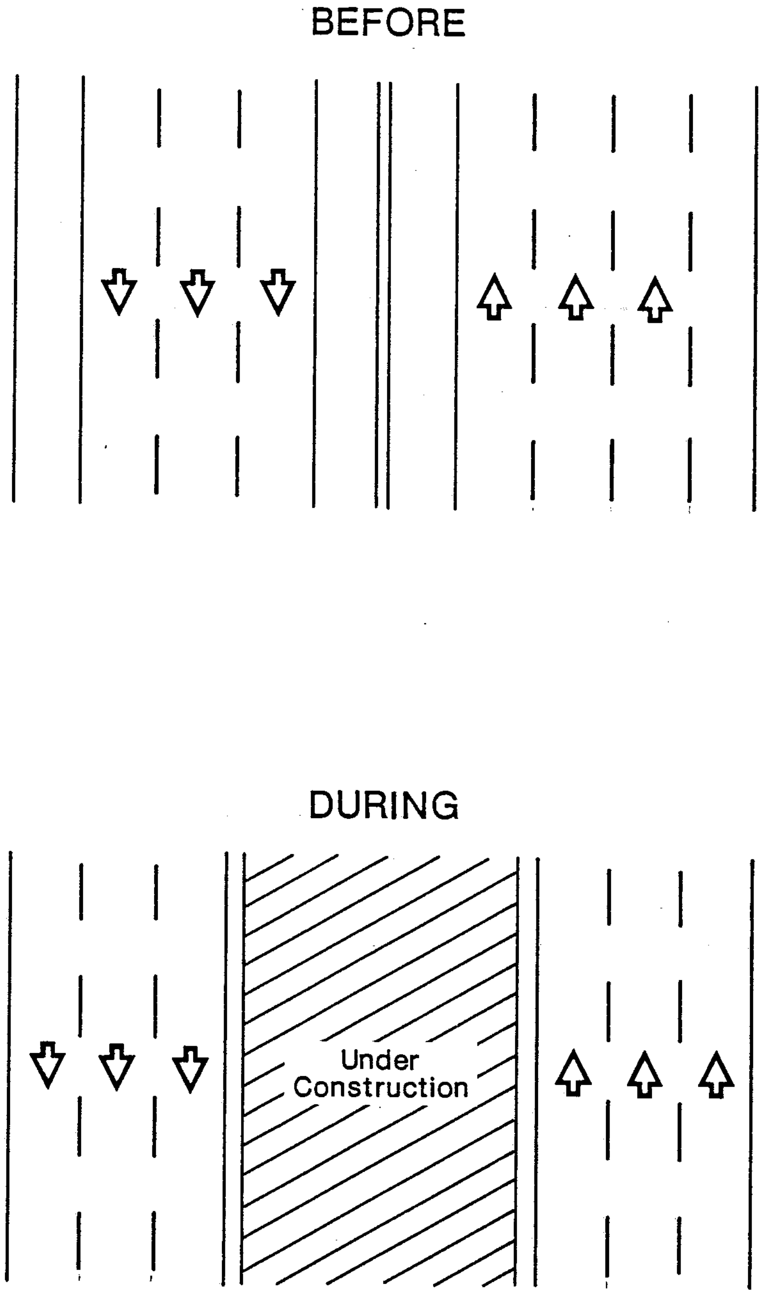


Figure A-6. Schematic of TCP Strategy for I-10 Construction.

I-81, Syracuse

I-81 is a major north-south Interstate highway running through Syracuse, New York. Figure A-7 illustrates the I-81 corridor through downtown Syracuse. In the late 1970s, the New York State Department of Transportation (NYSDOT) started a construction project to add two travel lanes on a 10-mi segment of the Interstate and to replace and modernize three major urban interchanges. The basic TCP strategy used throughout most of the project was to narrow lanes and reduce or eliminate shoulders through the construction zone. However, in 1984, bridge deck rehabilitation and substructure repair required the closure of the 2.8-mi three-lane viaduct and adjacent structures carrying southbound traffic through I-81 interchange with I-690. It was also necessary to close one northbound lane and slow traffic to 30 mph in order to minimize damaging vibrations in the southbound structure. Figure A-8 shows the TCP strategy used during the bridge rehabilitation. The closure was in effect from July to November 1984 (28,29).

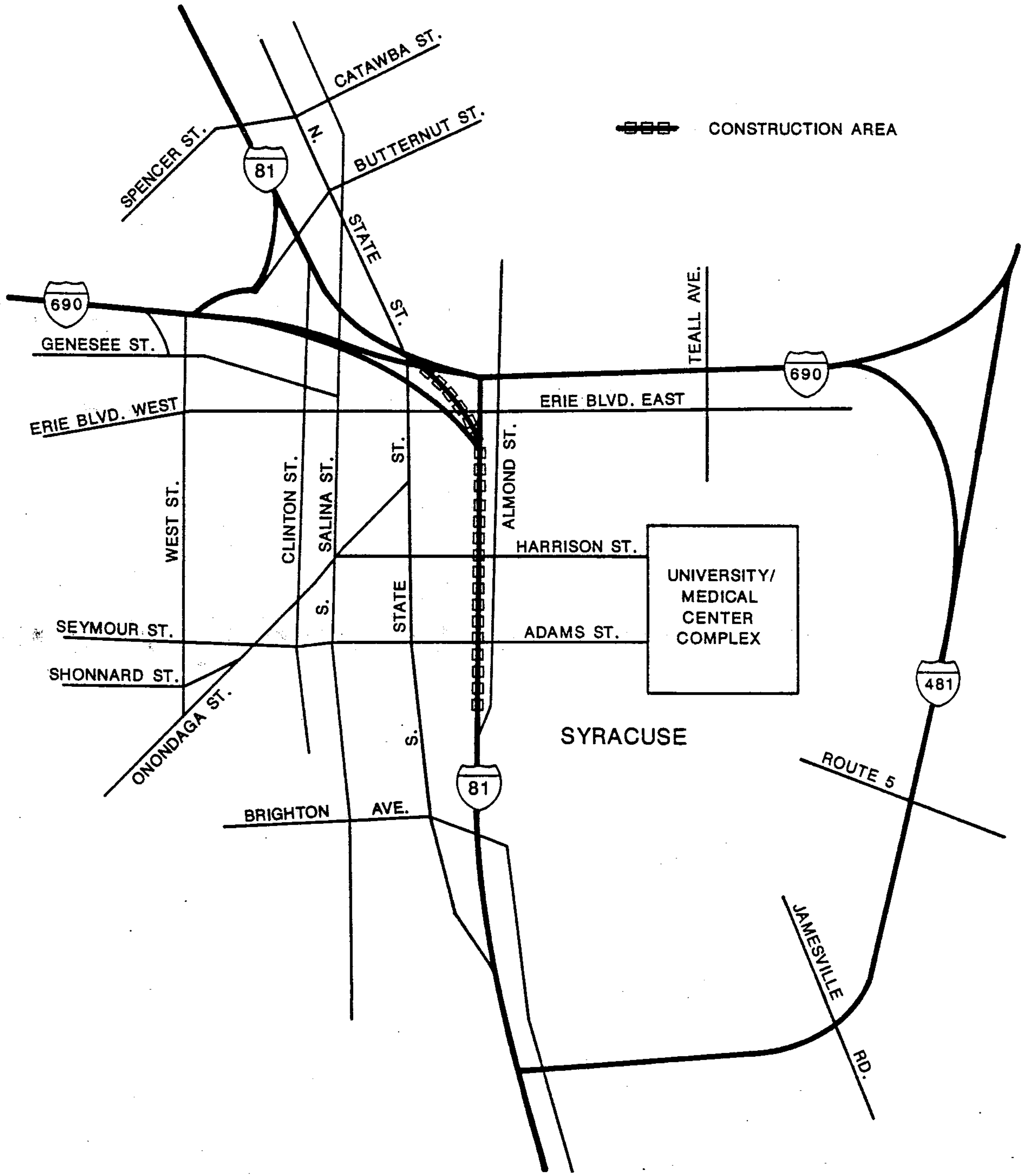
Project planners learned of the new federal policies that allowed the use of Interstate funds to mitigate the off-system impacts of Interstate construction in May 1984. In conjunction with FHWA and local transportation and police agencies, the NYSDOT implemented a package of traffic impact mitigation strategies and a public information program. The coordinated effort was called TOTE (for Total Transportation Effort).

The impact mitigation package included the following measures:

1. Improving traffic signal operations at 30 city street intersections;
2. Stationing city police and county sheriffs at critical locations to facilitate the flow of traffic;
3. Creating 5 park and ride lots;
4. Initiating express bus service from each park and ride lot at 15 min headways during rush hours;
5. Creating an exclusive HOV lane on an alternative route for buses, carpools, and emergency vehicles; and
6. Expanding the existing carpooling program to handle additional requests.

The public information program included:

1. Special traffic, information, and detour signs;
2. Brochures describing the TOTE program;
3. Newspaper advertisements;



Fiqure A-7. I-81 in Syracuse.

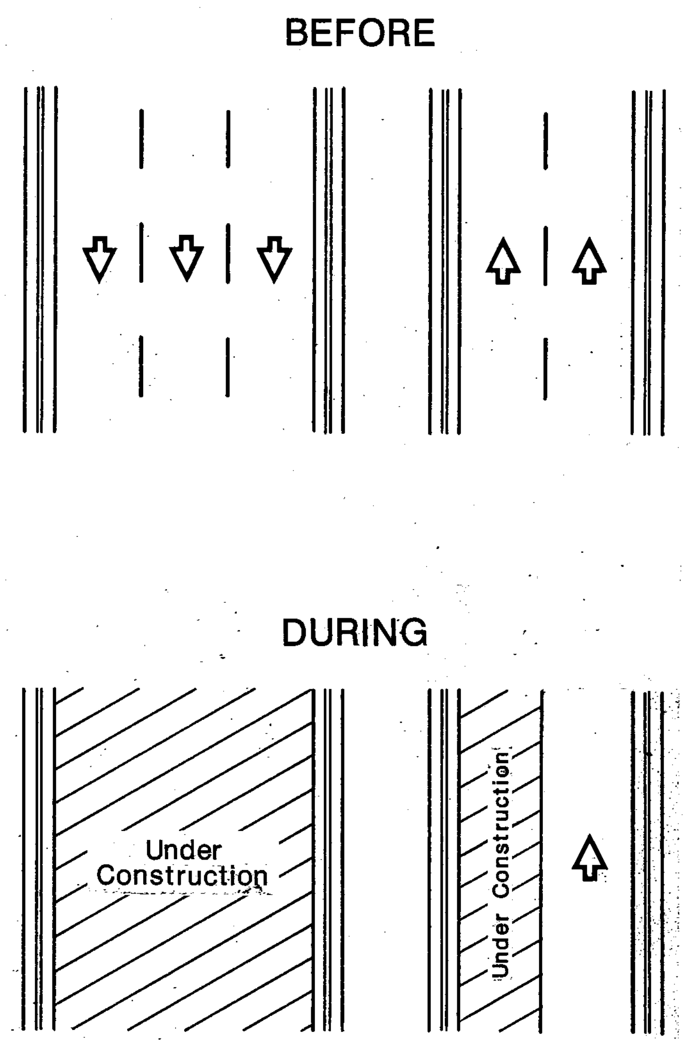


Figure A-8. Schematic of TCP Strategy for I-81 Construction.

4. Radio spots on 5 stations;

5. A major press conference;

6. Visits with the editorial boards of Syracuse's newspapers; and

7. Numerous special radio and television appearances.

The printed brochure describing the TOTE program presented 4 signed detour routes to help motorists traveling from the north on I-81 and from the west on I-690. In addition, the brochure pointed out other alternate routes that were not official signed detour routes. Meanwhile, it was felt that the other aspects of the public information campaign were quite successful in informing motorists of the closure. The media predicted severe congestion during the bridge rehabilitation. However, commuters apparently shifted their departure times in anticipation of this congestion. Consequently, traffic congestion during the first weeks was less than it had been immediately before the closure was in place. Congestion did increase by the end of the summer, though, as drivers became aware of less than anticipated delays, and the school year began. Paid radio advertising was effective, as were airborne traffic reports by the radio station during the rush hours. Police deployment had marginal effects as the season progressed, and the deployment was reduced accordingly.

Project planners had hoped that some aspects of the TOTE plan would have positive long-range effects, such as a continued spread of rush hour peaks, increased transit usage, and carpooling. The most substantial benefit was the improvement of traffic signals on the arterial streets. Long-term transit usage was disappointing, as it tapered off during the closure and had little residual effect. Similarly, park and ride lot usage continued to decline to the point where the lots eventually served only a limited number of commuters.

The major successes of the project were reported to be the public information program and the improvements made on the alternative routes. Overall, project officials ranked the cost-effectiveness of the strategies in the following order:

1. Open and frank discussion with the media before closure, aided by paid advertisements;

2. Traffic signal improvements on local streets;

3. Additional transit service in conjunction with park and ride lots;

4. Some of the police deployment;

5. Use of the HOV lane; and

6. Expanded carpooling service.

I-93, Southeast Expressway, Boston

As shown in Figure A-9, The Southeast Expressway is the only major highway facility connecting Boston with southeastern Massachusetts. The freeway facility has six lanes, with a discontinuous breakdown lane in each direction used as a travel lane during peak hours. The Expressway carried more than 160,000 vpd before construction. A $63.7 million construction project was undertaken by the Massachusetts Department of Public Works (MDPW) on an 8.5-mi section of the Expressway during the 1984 and 1985 construction seasons (March through November) 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 contract included a $10,000 per day incentive/ disincentive clause. The experiences from this project have been documented in an extensive report and in related articles (4-6).

The basic TCP strategy was to retain as much capacity as possible on the Expressway during construction. This was accomplished by (1) using concrete median barriers to divide the Expressway into four two-lane segments and (2) working on only one two-lane segment at a time. One 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 construction, and two lanes in the off-peak direction. This TCP strategy is shown schematically in Figure A-10. In addition, screens were installed on the sides of the work area to minimize potential reductions in capacity resulting from motorist rubbernecking.

Numerous actions were taken by the MDPW to mitigate the impacts of the construction both on Expressway users and on residents and businesses in affected communities. The philosophy was to provide as many travel options as possible to Expressway users. The actions included:

1. Providing increased commuter rail, boat, and bus service;
2. Adding park-and-ride lot spaces;
3. Supporting an employer-based ridesharing program and an information brokering program;
4. Encouraging employers to implement variable work hour or flextime programs;
5. Making traffic signal and pavement marking improvements at key intersections on alternative highway routes;
6. Placing police officers at certain intersections for traffic control;
7. Funding proposals from 15 communities to mitigate local traffic control problems resulting from the construction; and
8. Providing an extensive public information and community liaison program.

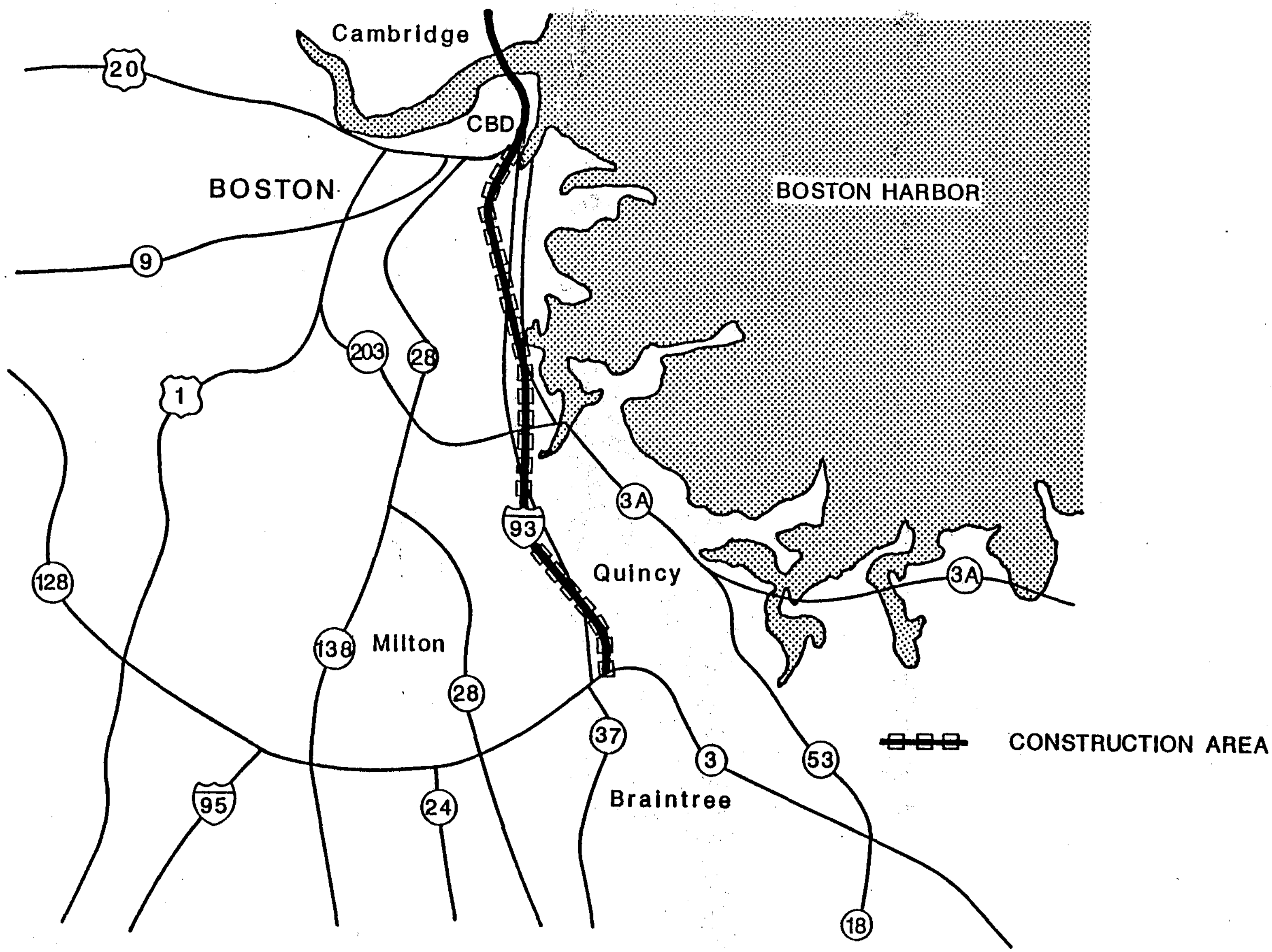
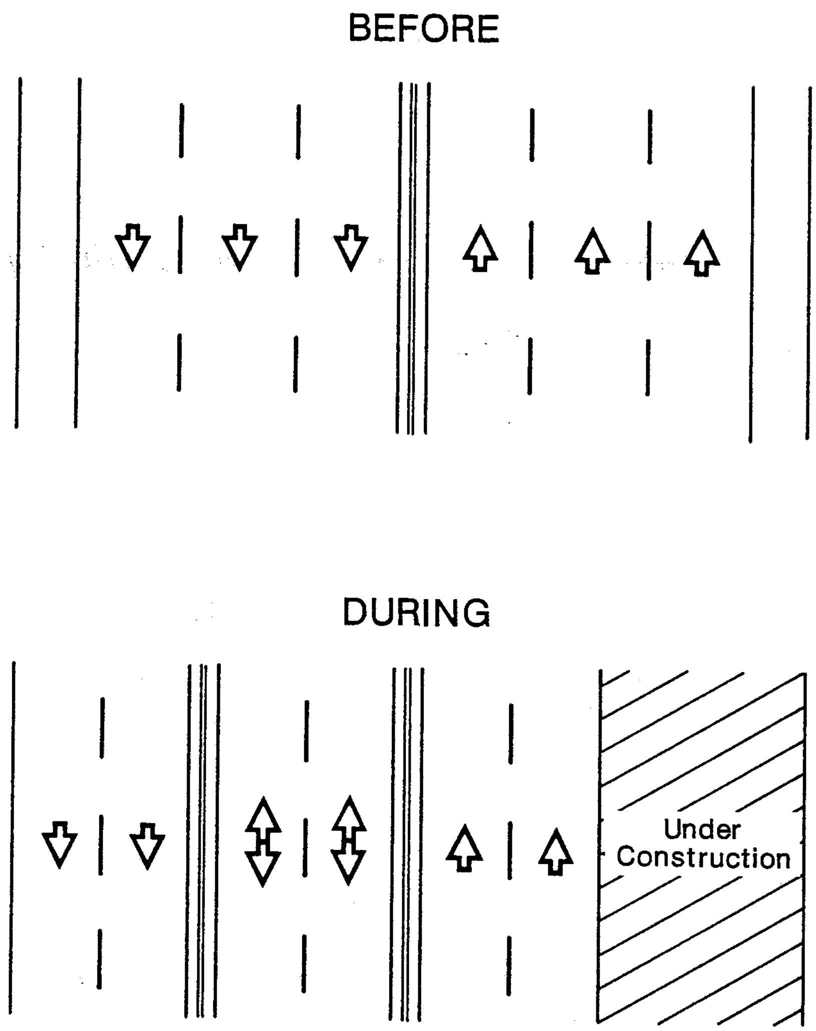


Figure A-9. I-93, Southeast Expressway, in Boston.



Fiqure A-10. Schematic of TCP Strategy for I-93 Construction.

The cost of these mitigating actions was $9 million. Flexibility was maintained to modify or discontinue actions that were ineffective. For example, much of the additional bus service was discontinued because it did not attract sufficient riders.

Analysis of conditions during construction indicated that it took several weeks for commuters to experiment with alternative routes and decide how to alter their tripmaking in response to the construction project. This was evidenced by fluctuations in traffic patterns during the first several weeks of the project.

During the first year of construction, between 5,000 and 9,000 vpd (3-6 percent of preconstruction volumes) diverted from the Expressway; but during the second year, volumes returned to preconstruction levels. Morning peak volumes were actually higher than preconstruction levels. The distribution of morning peak period volumes indicated a shift to earlier departure times during construction than before. The reductions in first year volumes were due to lower midday and afternoon peak volumes. Officials in Boston speculated that the reason for these lower volumes was the reduction of discretionary midday trips.

The data also suggested that most of the diverting traffic 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; however, some of these increases were attributed to improvements in service and not to the negative impact of construction. 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 construction.

I-5, Ship Canal Bridge, Seattle

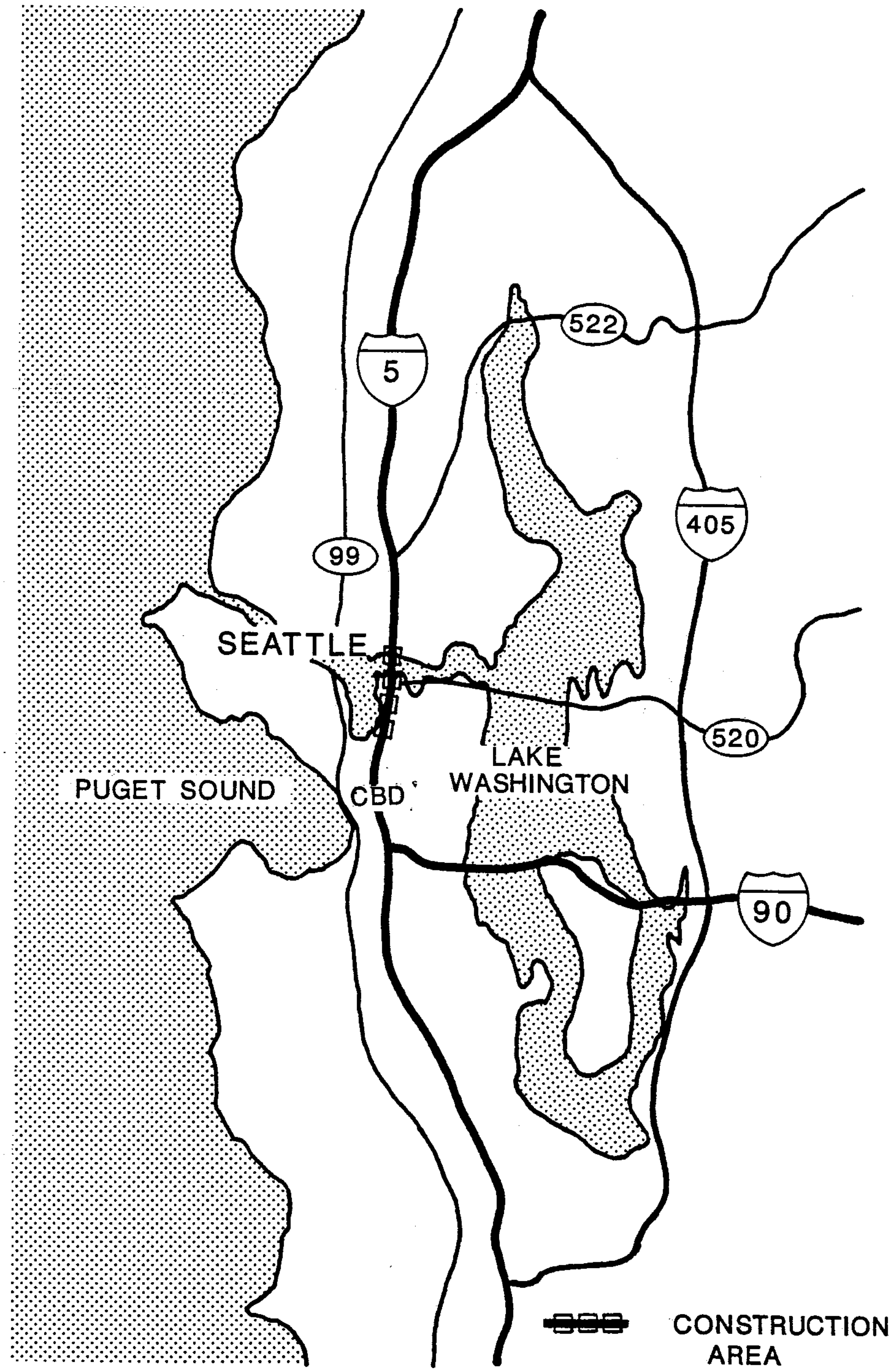
I-5 is the major north-south freeway running through Seattle. Figure A-11 shows this freeway corridor. It includes an eight-lane freeway and a separate two-lane reversible roadway. The reversible roadway runs north from the central business district for 8 mi and serves as express lanes. A project was undertaken by the Washington State Department of Transportation (WSDOT) to resurface the main lanes of the Ship Canal Bridge and the Lakeview/Galer Viaduct on I-5 (25,26). The average weekday traffic on this section of I-5 before resurfacing was 210,000 vpd.

A 1-mi section of the northbound (outbound) main lanes was resurfaced during the summer of 1984 and a 2-mi section of the southbound (inbound) main lanes was resurfaced during the summer of 1985. The contract for the northbound lanes included a $10,000 per day incentive/disincentive clause, and the contract for the southbound lanes included a $20,000 per day incentive/ disincentive clause.

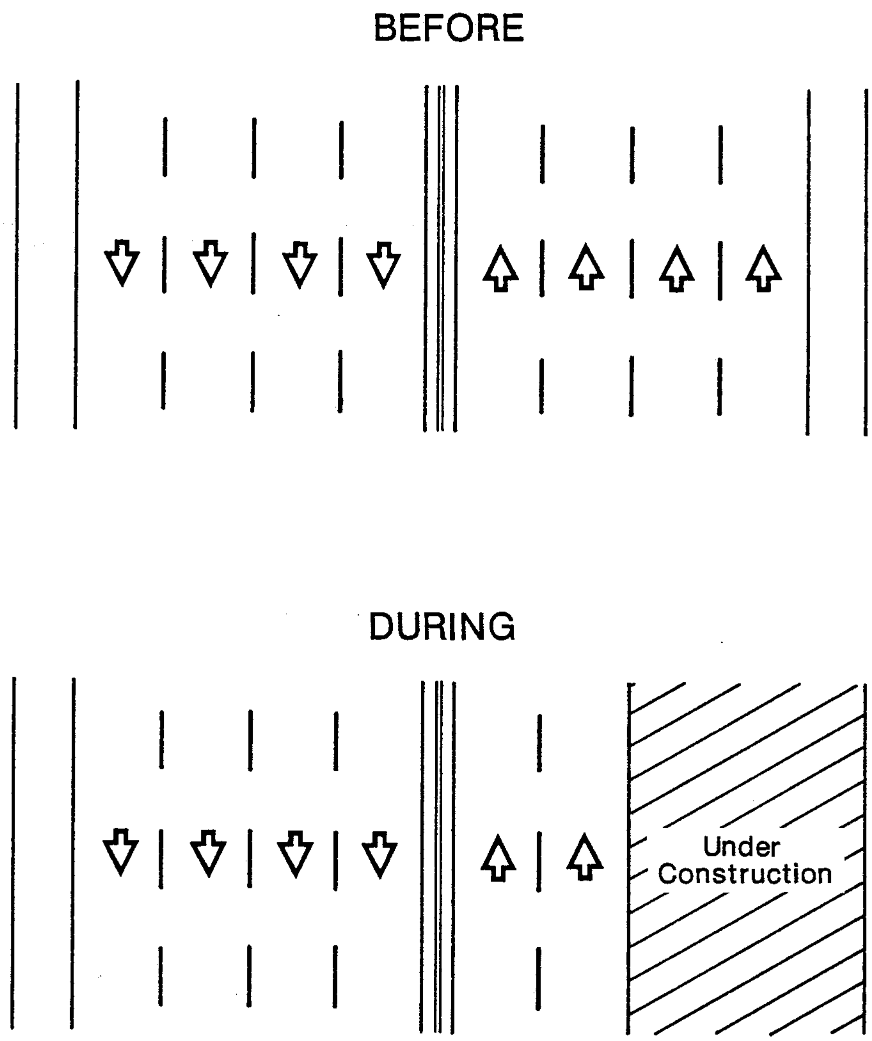
The resurfacing project on the northbound lanes in 1984 had three phases. In the first phase, preparatory work (repairing joints and grinding the surface) was performed in two-lane segments on week nights during off-peak hours (8 p.m. until 6:30 a.m.) and on weekends. This strategy required the installation and removal of lane closures nightly. During the day, all travel lanes were open, but traffic was slowed by the rough surface. In the second phase, two lanes at a time were closed for placing and curing the 1.5-in concrete overlay. Traffic was maintained on two 11-ft lanes with a 1-ft left shoulder and a 1.5-ft right shoulder. In the third phase, lanes were closed during week nights and weekends for final cleanup operations.

After the completion of the northbound resurfacing project, officials reviewed the traffic management strategy that was employed. They concluded that the daily traffic control setup not only caused the project to take longer than expected but also confused the driving public because of the frequent changes in traffic patterns. Therefore, during the resurfacing of the southbound lanes in 1985, a PCB was used to close two lanes at a time through the length of the project while all preparatory work and paving were completed in those lanes. This strategy is depicted in Figure A-12. This traffic control plan was considered superior because it allowed the contractor to work more efficiently (evidenced by the fact that the southbound work was completed in less time than the northbound even though the length resurfaced in the southbound direction was greater) and it provided a more stable driving environment.

During the project planning process, it was determined that it would not be possible to accommodate normal traffic volumes with two lanes closed. Therefore, a coordinated effort was undertaken to reduce the volumes on I-5 and to minimize the adverse travel impacts on motorists. The strategy was to take advantage of the express lanes as an alternative route and of the strong mass transit and carpool/vanpool organizations in Seattle.



Fiqure A-11. I-5, Ship Canal Bridge, in Seattle.



Fiqure A-12. Schematic of TCP Strategy for I-5 Construction.

The use of alternative routes, including the express lanes, was encouraged by:

1. Constructing cross-over ramps from the main lanes to the express lanes,

2. Expanding the hours of operation of the express lanes in the direction being resurfaced,

3. Retiming traffic signals on alternative routes,

4. Restricting maintenance work on alternative routes to emergency operations only, and

5. Using off-duty police officers for traffic control at critical alternative route locations.

Bus transit and carpool/vanpool usage was encouraged in several ways:

1. Restricting two downtown ramps to HOV only,

2. Adding several new bus routes,

3. Making backup buses available for service in the event of delays to regular buses in route, and

4. Disseminating carpooling information.

Traffic operations on I-5 were monitored using the Surveillance, Control, and Driver Information System operated by the state's Traffic Systems Management Center. The center also dispatched state patrol cars and the tow trucks which were provided by the contractor, and also provided up-to-date traffic reports to the metropolitan transit agency and to local radio stations.

A public information plan was also implemented. Information was disseminated through news conferences and public hearings; brochures, posters, letters, and flyers; a 24-hour Resurfacing Hotline; a Highway Advisory Radio station; and variable message signs.

The project was completed without serious congestion either on I-5 or on the alternative routes. Average weekday traffic decreased by 38 percent on the main lanes in 1984 and by 40 percent on the southbound main lanes in 1985. Much of the traffic diverted to either the express lanes (40 percent) or to one of the five parallel alternative routes that cross the Ship Canal (40 percent). The remaining diverted trips used other routes, changed modes, or were not made. Some diversion to HOVs also occurred: requests for ridematching increased 56 percent in August 1985 compared to August 1983, and bus ridership in the summer of 1985 was 10 percent higher than normal.

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. The topographical layout of roadways in this corridor is shown in Figure A-13. The 21-mi long freeway is predominantly four lanes, although several segments near downtown have six or eight lanes. Traffic volumes ranged 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 a three-year, $175 million construction project to (1) rehabilitate 18-mi of pavement, (2) rehabilitate 50 bridges, (3) widen shoulders, and (4) replace the metal guardrail in the median with concrete median barrier.

The construction project began in 1985, when a 5-mi segment near the Turnpike and a 1.5-mi segment at the downtown end of the Expressway were constructed. In 1986, 12-mi were rehabilitated. Construction of a major downtown interchange, was originally scheduled for completion in 1987. However, design and construction problems were encountered which delayed the remaining work to 1988. The construction work in 1985 and 1986 was performed under five separate contracts. Each contract included an incentive/disincentive clause which varied from $21,875 to $30,000 per day. The project has been described in several articles (22-24).

To assist in project planning, PennDOT retained a traffic engineering consultant to (1) establish and analyze the existing transportation situation, (2) develop construction 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.

Officials decided to stage the project over three construction seasons (March to November). The traffic management plan had three goals: (1) maintain at least one lane of traffic on the Expressway in each direction at all times, (2) encourage truck drivers, tourists, and other long-distance travelers to remain on the Expressway during construction, and (3) reopen all lanes of traffic between construction seasons.

In general, two-lane two-way traffic was maintained on one directional roadway while work was performed on the other directional roadway. Shoulders were upgraded prior to construction. This enabled traffic to operate on the shoulder and on the median lane with a buffer lane in between the two lanes of traffic. Figure A-14 illustrates the TCP strategy used during construction. Most of the entrance ramps and some of the exit ramps within or leading to the construction zone were closed in order to limit access to the Expressway by local drivers.

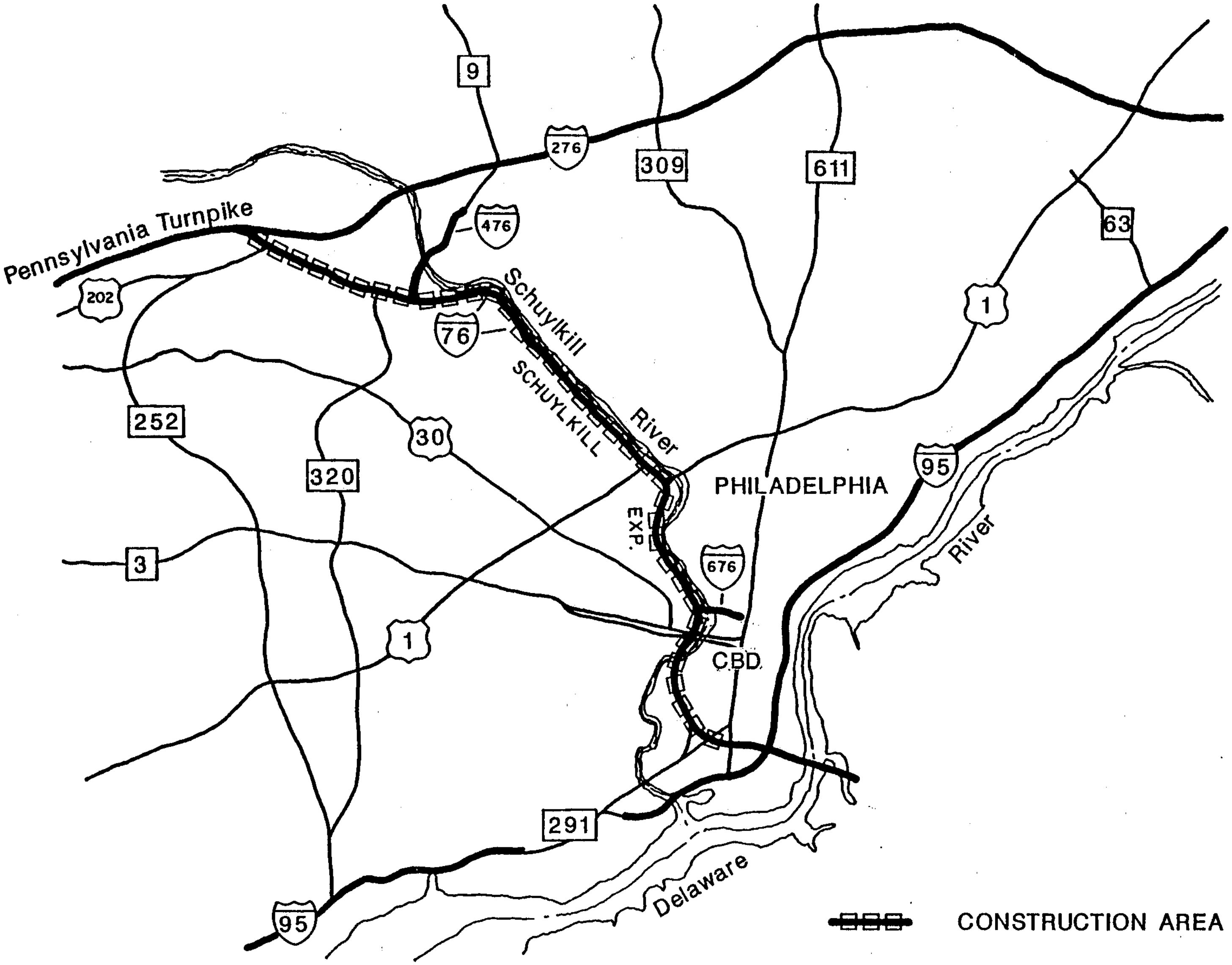
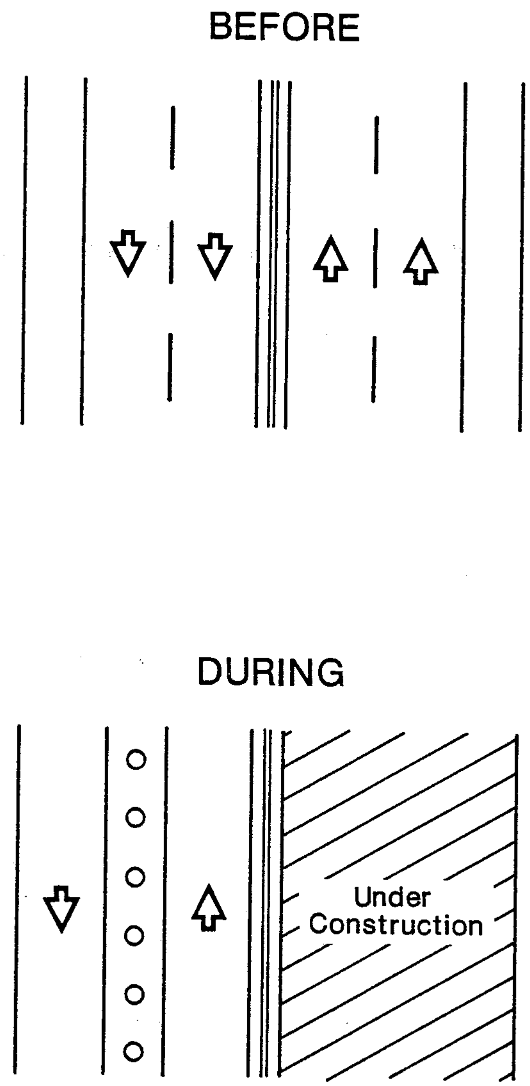


Figure A-13. I-76, Schuylkill Expressway, in Philadelphia.



Fiqure A-14. Schematic of the TCP Strategy for I-76 Construction.

The alternative routes and the public transportation system in the Schuylkill Expressway corridor were not considered capable of handling the traffic that would have to divert from the Expressway due to the reduction in Expressway capacity. Therefore, a program of mitigation measures was undertaken to increase the capacity of alternative routes and to improve public transportation facilities and services. The program was budgeted at $12 million.

Improvements on alternative routes included:

1. Modernizing, coordinating, and retiming existing traffic signals;

2. Installing additional signals (some permanent and some temporary);

3. Widening and constructing intersection turning lanes;

4. Eliminating on-street parking;

5. Accelerating maintenance and pavement patching schedules on key routes; and

6. Assigning traffic control officers to key intersections and school bus stops.

Improvements to public transportation facilities and HOV services included:

1. Expanding park-and-ride lots,

2. Extending commuter rail service farther west,

3. Adding rail cars on existing trains in the corridor,

4. Adding buses to maintain preconstruction headways on existing routes, and

5. Increasing ridesharing programs.

An extensive public information program was also undertaken. The program included:

1. Traditional public relations tools (press conferences, news releases, interviews, media events, and public service announcements);

2. A Visitor's Guide, which provided information and encouragement for truckers, tourists, and long-distance travelers to stay on the Expressway;

3. A Commuter's Guide, which provided information and encouragement for local drivers to take alternative routes; and

4. A toll-free hotline to identify alternative routes, answer questions, take and respond to complaints, and distribute information.

Preliminary analyses of the actual travel impacts suggest that traffic volumes on the Expressway decreased by 60 percent during the first construction season. The traffic that diverted was widely dispersed over a large number of alternative routes. The volume counts also suggested that motorists shifted back and forth between the Expressway and the alternative routes in response to changing traffic conditions.

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 A-15 identifies the 11-mi segment of US 12 from Trunk Highway (TH) 101 to downtown Minneapolis that is being constructed 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 ADT on US 12 in 1984 ranged from 49,000 vpd just east of I-494 to 99,000 vpd just west of Penn Avenue (7).

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 plan for the corridor (8).

The construction project began in 1985 and is scheduled for completion in 1992. The project includes the construction 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.

The fundamental design objective for I-394 was to maximize the people carrying capacity of the corridor. The I-394 Transportation 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, ridesharing programs, and downtown parking garages.

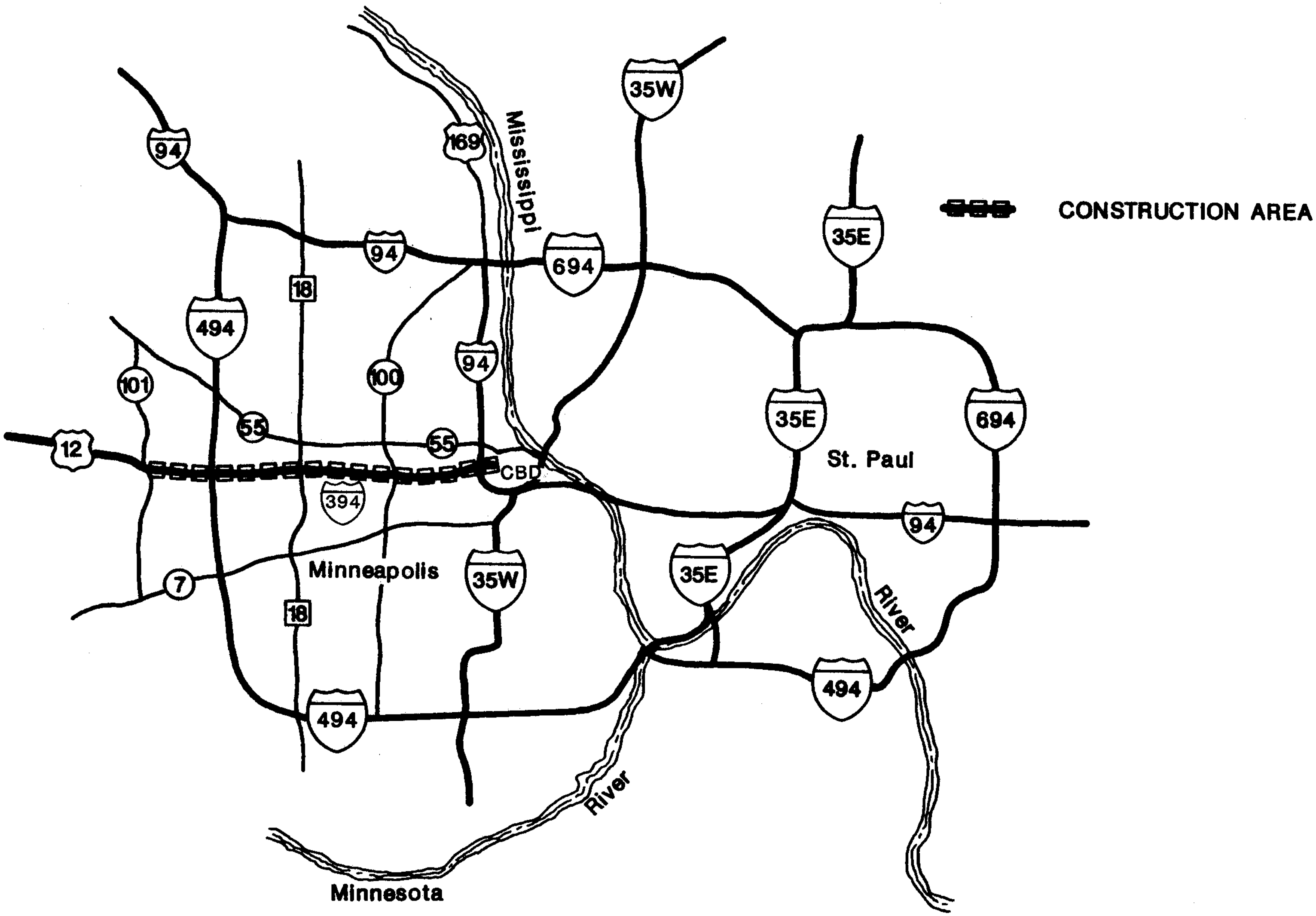


Figure A-15. I-394 in Minneapolis.

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 policies were established (8):

1. At least two through lanes of mixed traffic in each direction during peak periods would be maintained during construction.

2. A single reversible lane or diamond lanes would be provided, where cost-effective, for HOVs during peak periods before and during construction. These HOV lanes would be in addition to four through lanes for mixed traffic.

3. Reasonable access would 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 ridesharing programs would 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. Consequently, it was decided 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. Figure A-16 presents a schematic of the TCP strategy used during construction.

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 would have 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 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 (9).

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.

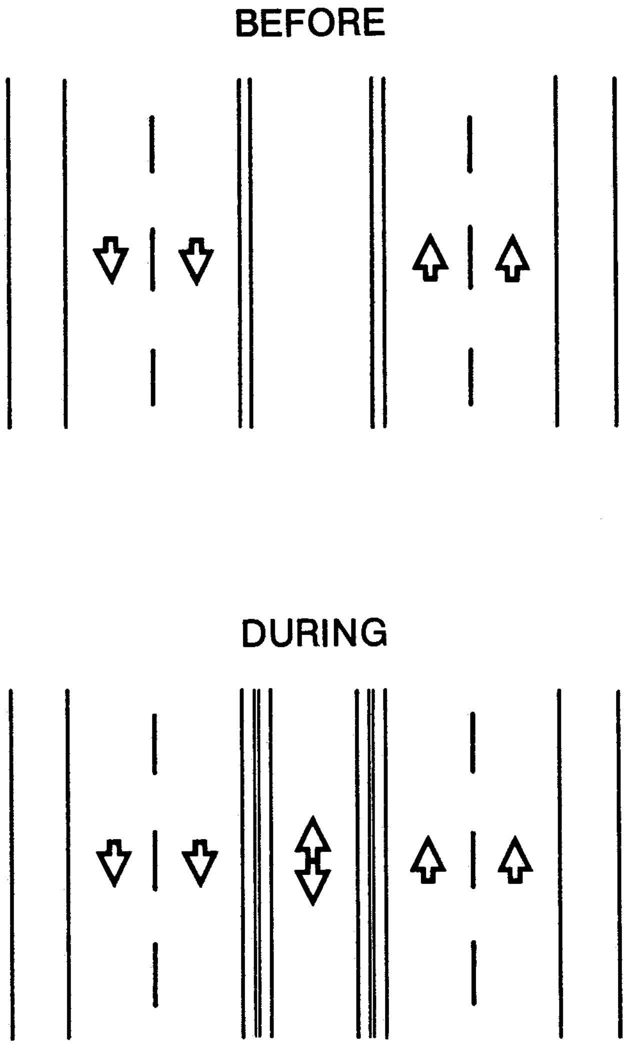


Figure A-16. Schematic of TCP Strategy for I-394 Construction.

Standard procedures were used to perform a cost-benefit analysis of the lane (76). Costs were estimated for the construction, maintenance, and operation of the HOV lane. 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. 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 1.2, for the low estimate of usage, and 1.6, 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 of 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 A-15 illustrates two parallel alternative routes to US 12: TH 55 and TH 7. 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 I-394 project. Many of the improvements were needed anyway, but MnDOT wanted to complete the improvements before the I-394 project began in order to maximize the capacity available on TH 55 during the I-394 project. TH 7 is a heavily traveled city street. No major improvements were made to this route because of limited right-of-way.

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 preconstruction volumes.

FHWA sponsored an evaluation of the effectiveness of the HOV lane based upon the first year of operation. The evaluation concludes that "The I-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" (9). 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 to be between 1.1 and 1.3.

US-10, John C. Lodge Freeway, Detroit

The Lodge Freeway is a six-lane freeway connecting downtown Detroit and its northwestern suburbs. The Freeway, shown in Figure A-17, carries approximately 130,000 vpd. In 1986, the Michigan Department of Transportation undertook a $39 million project to construct a 7.8 mi section of the Freeway between I-75, near downtown, and Wyoming Avenue, to the northwest. The project includes (1) widening the outside shoulders, (2) constructing a safety shaped barrier wall at the edge of the outside shoulders, (3) extending and upgrading the drainage and storm sewer system, (4) removing and replacing the pavement, (5) improving several interchanges, (6) redecking several bridges, (7) improving landscaping and erosion control, and (8) repairing the pavement on a new section of the freeway north of the project limits. The two-year project began in April 1986 and was scheduled to take two construction seasons (April through November). The contracts for the work include $12,000/day incentive/disincentive clauses. Documentation of the project can be found in two articles (30,31).

The work conducted in 1986 (primarily items 1-3 above) required only narrow lanes and shoulders on the Freeway. All three lanes were kept open in the peak direction during rush hours. The outside lane in each direction was allowed to be closed during off-peak periods. Lanes were narrowed from 12 to 11 ft, and the median shoulders were narrowed by 3-ft to provide a 6-ft right shoulder. Ramps were closed, but no more than two consecutive ramps at a time. During special events, all lanes and ramps were kept open. A 45 mph speed limit was established through the construction zone. The capacity reductions in 1987 were more severe. One direction of the Freeway at a time was closed for the pavement removal and replacement. Figure A-18 shows the basic TCP strategy used during the 1987 construction season.

Project planners estimated that the alternative routes in the corridor could handle 78 percent of the traffic expected to divert from the Freeway in 1987. The use of HOV modes and other city streets would have to accommodate the rest. Planners estimated that travel times in the corridor would increase by 20 percent.

To reduce the adverse effects of construction on motorists, improvements were made to alternative routes, including:

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 traffic signals.

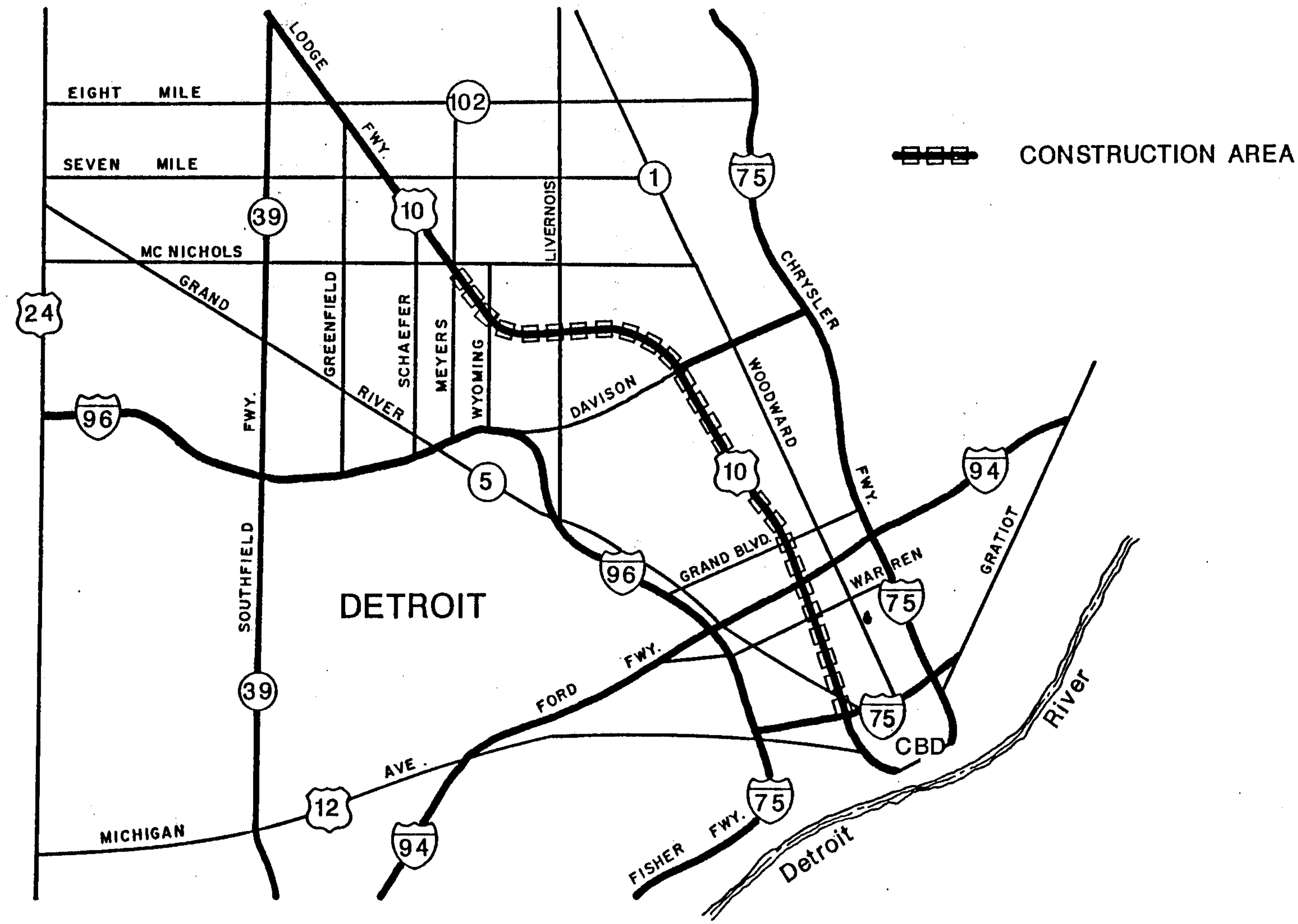
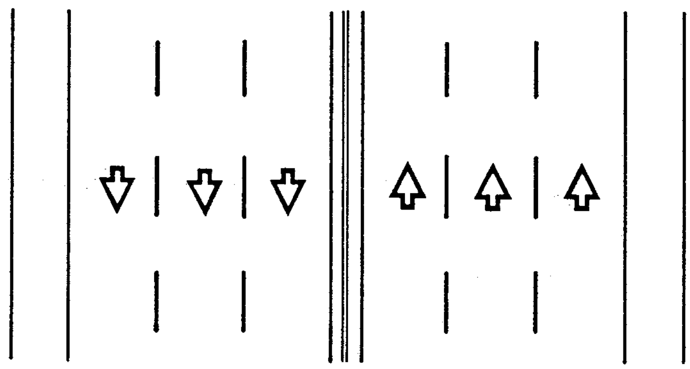
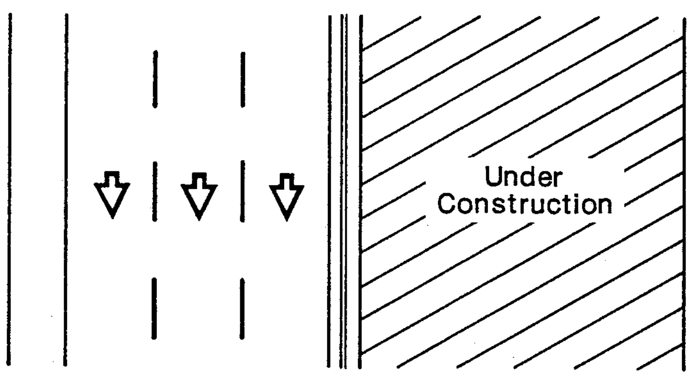


Figure A-17. US-10, Lodge Freeway, in Detroit.

BEFORE



DURING



Fiqure A-18. Schematic of TCP Strategy for US-10 Construction.

Improvements were also made in HOV services in the corridor, including:

1. Increased efforts to attract carpoolers and vanpoolers, and

2. Expanded bus service.

Motorist services that were provided included:

1. Free tow truck service on the Freeway within the construction project limits, and

2. Increased police patrols on alternative routes.

A public information program was also implemented by a public relations consultant. The public information program included:

1. Traditional public relations tools (public meetings and presentations, media briefings, public service announcements),

2. Informational signing,

3. Distribution of a variety of informational materials,

4. A telephone hotline, and

5. An ombudsman.

Even though the capacity restrictions in 1986 were relatively minor compared with 1987, the impact mitigation strategies were implemented in 1986. Motorists were encouraged to prepare for 1987 by identifying and starting to use alternative routes and modes. The strategies appeared to have had positive results. Officials estimated that traffic volumes on the Freeway during the 1986 construction season were almost 20 percent lower than preconstruction levels. Measurements taken during the 1987 construction season showed that signal timing and other roadway improvements made on two arterial routes in the corridor allowed the arterials to handle 40 to 60 percent more traffic with little or no increase in travel times (31).

I-91, Hartford

Interstate 91 in Connecticut is currently undergoing construction from the city of Hartford north to the Massachusetts state line, a distance of 19.5 mi. Figure A-19 illustrates the travel corridor for this freeway. The facility, currently a four-lane, divided, limited-access roadway, is being widened to a six-lane roadway. In addition, HOV lanes are being added in each direction from Hartford to Route 159 in Windsor Locks. Even before construction began, traffic demands exceeded available capacity during peak periods. Consequently, it was decided to maintain at least two travel lanes per direction during construction. Even then, project officials feared that the side friction caused by work areas adjacent to the freeway could reduce lane capacities to as low as 1250 vehicles per hour per lane. If this were to occur, up to 1500 vph would have to be diverted from the Freeway during peak periods.

Given the potential for significant disruptions to traffic because of I-91 construction, a Task Force for the I-91 construction project was established in 1983. The Force, consisting of members of the Connecticut Department of Transportation (ConnDOT), City of Hartford Public Works Divisions, FHWA, Greater Hartford Transit and Ridesharing groups, and Capital Region Council of Governments was assigned the task of developing and identifying traffic management strategies to optimize the available corridor capacity. The groups actions were presented as recommendations in a final report to ConnDOT (11). The total package of recommendations was estimated to exceed $16,000,000 in capital costs (1987 dollars), and included the following categories of actions:

1. Improving alternative routes (resurfacing, intersection widening, expediting installation of a computerized traffic signal control system for Hartford),

2. Expanding commuter rail service,

3. Expanding commuter bus service,

4. Initiating a ridesharing program for I-91 commuters,

5. Expanding existing park-and-ride lots and initiating new ones throughout the corridor, and

6. Initiating ramp metering along I-91.

A key to the traffic management plan for I-91 is the flexibility of implementation of the selected actions. For example, the Task Force concluded in 1984 that commuter rail service was not a feasible option at that time. However, the doors of communication with officials of AMTRAK and others have been kept open in the event that traffic conditions on I-91 degrade to the point that rail service becomes viable. Likewise, an analysis of ramp metering on I-91 indicated that the system would not result in significant benefits to I-91 users and so was not implemented. The Task Force solicited the help of a non-profit ridesharing company in Hartford to help promote HOV travel on I-91 during construction. The company has tried to promote bus ridership by offering free monthly bus passes to

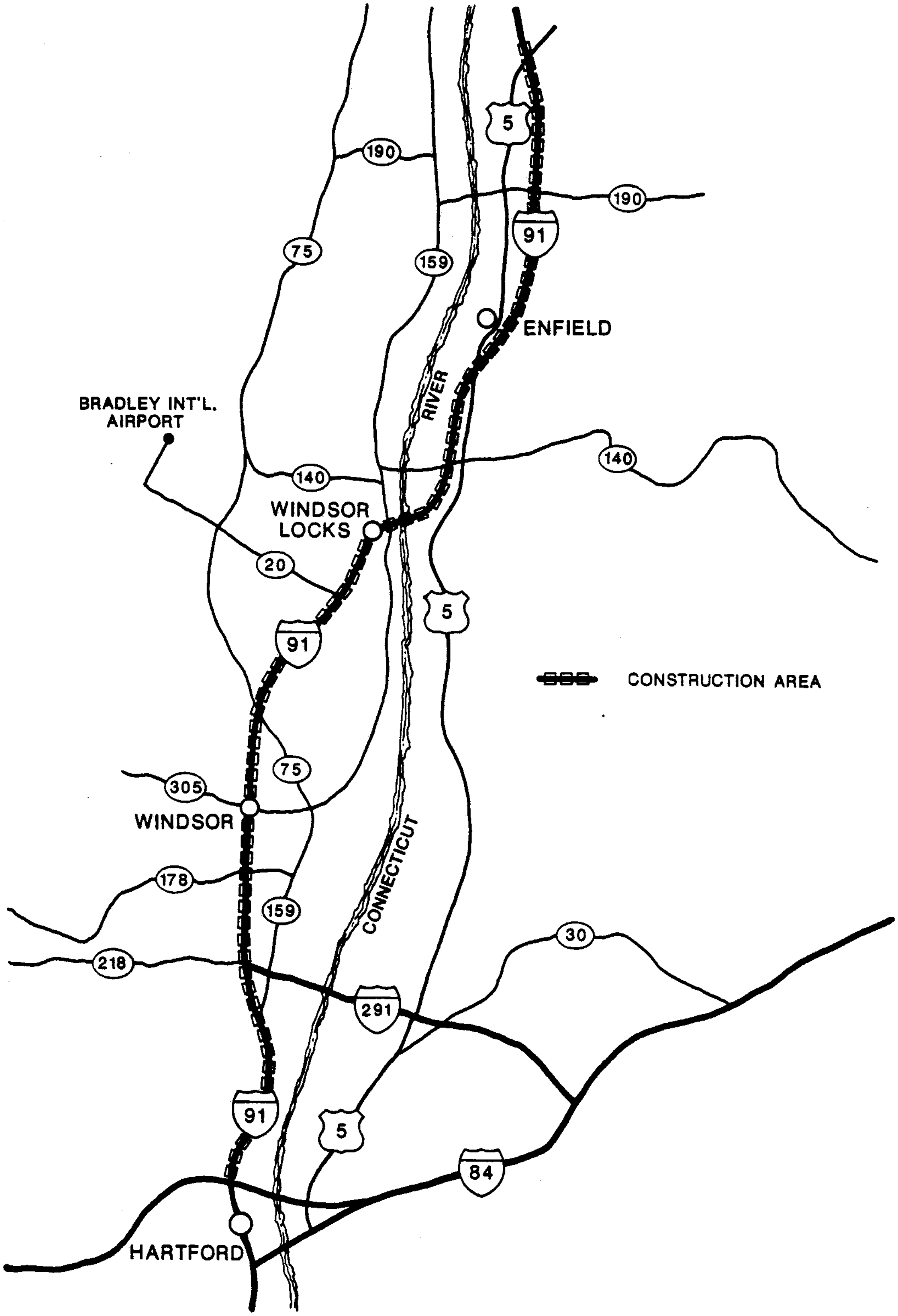


Figure A-19. I-91 in Hartford.

qualified I-91 commuters. Other actions and promotions by this company are planned as well.

A public information program for this project has been developed around the introduction of ridesharing to the corridor. As part of this program, a Commuter's Register would be developed to provide information about owner and operators of leased vanpools, general information about ridesharing, commuter park-and-ride lot locations, alternative travel route locations, construction progress, transit information, and flextime information. This newsletter would be disseminated via direct household mailings, retail outlet locations, and newspaper inserts. In addition to the newsletter, traditional forms of public information would be provided (news releases, neighborhood and community meetings, and telemarketing). Finally, information would be provided along the construction zone through special signing, billboards, and radio publicity. Two levels of promotions were evaluated, costing $72,000 for the low level and $91,000 for the high level campaigns, respectively.

Construction along I-91 has been hampered somewhat by legal battles, the most notable of which is a suit filed against the USDOT, FHWA, and ConnDOT by the town of Windsor. The location of Windsor is shown in Figure A-19. Town officials had serious concerns regarding proposed Freeway access to and from their town. In addition, the town was worried that increases in traffic on its streets would accelerate pavement wear and increase congestion. An agreement was eventually reached between ConnDOT and Windsor that (1) gave the town final approval of the redesign of access to and from the Freeway, (2) required ConnDOT to provide additional improvements to be performed on their streets and at their rail station, and (3) specified that ConnDOT would be responsible for repairing damage to the town's streets due to increased traffic.

Little information is available regarding the traffic impacts of I-91 construction at this time. The majority of the work has been in the northern section of the project, where impacts were not expected to be severe. As work in this portion of the project continues, the remaining improvements on alternative routes and modes are being completed for the time that construction begins on I-91 between Hartford and Windsor. It is this section that will determine how successful the Task Force has been in providing a satisfactory traffic management plan for I-91 construction.

I-94, Milwaukee

I-94 is the principal route from the south into downtown Milwaukee. In 1987, the Wisconsin Department of Transportation (WDOT) initiated a three-year construction project on a 5-mi segment of the freeway immediately south of downtown. At the northern (downtown) end of the segment, traffic volumes approached 125,000 vpd, on the eight lane freeway. The project involves pavement resurfacing, shoulder construction, bridge deck repairs and/or replacement, and widening. Figure A-20 illustrates the corridor. The effects of the 1987 construction season upon traffic in the corridor have been documented (27).

After considering several possible TCP strategies for construction, it was decided to allow two lanes in each direction to be closed at a time, and to maintain two lanes of traffic flow per direction through the construction zone. Figure A-21 presents a schematic of the TCP strategy during 1987. Project officials estimated that this TCP strategy would result in approximately 50,000 vpd diverting from the Freeway, with about 2600 vph diverting during peak periods. A network traffic assignment and analysis, performed by the regional planning commission, indicated that the local street network in the corridor had the capacity to accommodate the anticipated diverted traffic from the Freeway. However, traffic operations improvements would be necessary at key intersections and street segments within the corridor. The improvements to the various alternative routes in the corridor included:

1. Traffic signal timing and phasing changes at 66 locations,

2. Improvements in signing and pavement markings,

3. Parking restrictions, and

4. Installation of two temporary traffic signals.

Also, additional school crossing guards were placed at selected intersections on the alternative routes to insure the safety of school children and pedestrians.

Project officials also took steps to encourage the use of alternative modes of transportation in the corridor during construction. Additional transit service was provided on the local streets in the corridor, and additional express bus service was provided on the freeway. A marketing effort (involving direct mailings, free ride coupons, radio and television advertising) was under taken to promote the use of transit.

An extensive public information program was undertaken as part of the construction project. The objectives of the program were to help reduce congestion on the freeway, to promote safety through the construction zone and on alternative routes, and to encourage motorist tolerance of the inconveniences the construction project would cause. Components of the total program included:

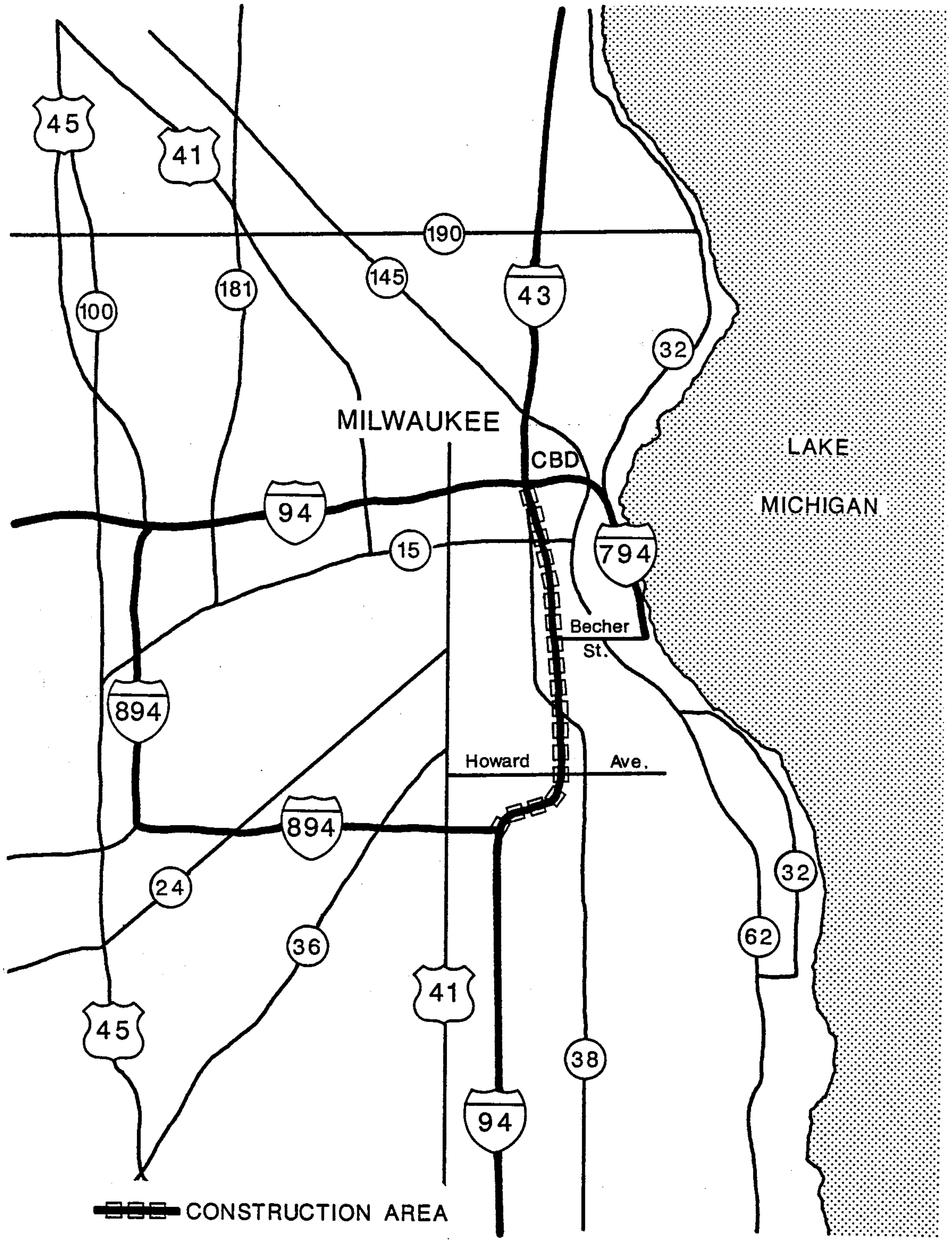


Figure A-20. I-94 in Milwaukee.

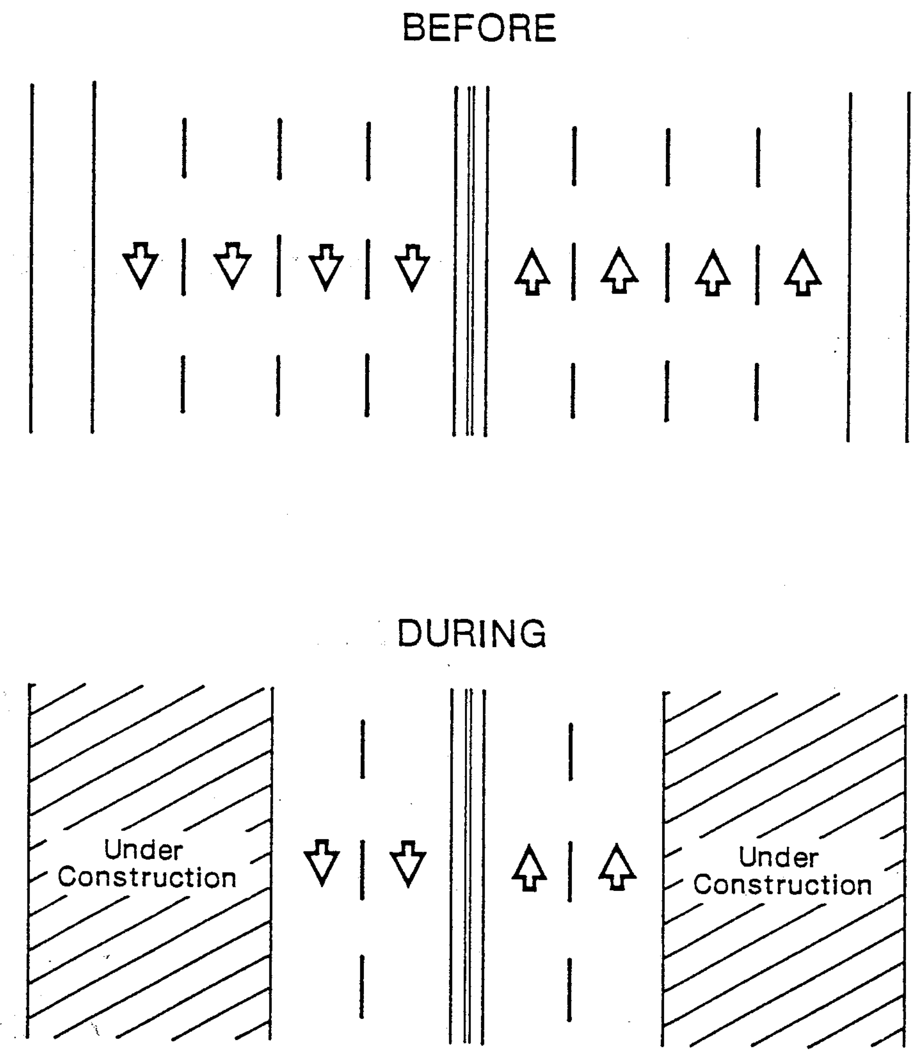


Figure A-21. Schematic of TCP Strategy During I-94 Construction.

1. Extensive media coverage of the project by newspaper, radio, and television;

2. Numerous meetings with local elected officials, businesses in the corridor, and neighborhood groups;

3. Paid radio advertising spots;

4. Paid newspaper advertisements;

5. A telephone hotline;

6. Visitor brochures distributed at the airport, hotels, motels, and visitor centers; and

7. Freeway signing on approaches to the construction zone that encouraged through traffic to use the I-894 by-pass (see Figure A-20).

Conditions during construction showed the traffic operations improvements, transit improvements, and public information programs to be very successful. Traffic counts within the construction zone were approximately 55,000 vpd lower during construction. Much of this traffic was traced to local alternative routes in the corridor and to the I-894 by-pass. Still, an average of about 17,500 vpd could not be accounted for within the corridor. It was speculated that this traffic used routes outside the study corridor, eliminated optional trips, or changed travel modes. Transit usage on the local street system and on the express bus service on the freeway increased by approximately 1100 trips per day.

Even with the additional traffic on the alternative routes in the corridor, travel times on these routes increased an average of only one to two min. Meanwhile, travel times on the Freeway remained virtually unchanged. Accident experience within the construction zone and on the approaches to the zone increased approximately 10 percent during construction.

I-95, Miami

I-95 is the Interstate highway that runs along the Atlantic Coast from Maine through Florida. The south Florida portion of this freeway corridor is shown in Figure A-22. A 44-mi segment of I-95 between Boca Raton and Miami is scheduled to undergo construction during the time period 1987-1991. The boundaries of this project are from State Route (SR) 836 in Dade County to Yamato Road in Palm Beach County. This segment of I-95 is a six-lane freeway. Traffic counts at key locations during the peak travel months of February and March of 1987 ranged between 150,000 and 180,000 vpd. The I-95 corridor is unique in that it is long and narrow--bounded by the Atlantic Ocean to the east and the Everglades Swamp to the west. The area is an international resort, and during the winter months traffic volumes remain at peak levels throughout the day.

The scheduled improvements to I-95 include the addition of HOV, through traffic, and auxiliary lanes to the freeway. The completed facility will have 10 to 12 lanes, 2 of which will be HOV lanes. Through one key interchange, the cross section will have 15 lanes. Extensive construction of the mainline and several crossroads is scheduled over the five-year duration of the project. In addition, other roadways in the corridor, including existing US-1, US-441, Florida's Turnpike, and the new I-595, will be under construction at the same time.

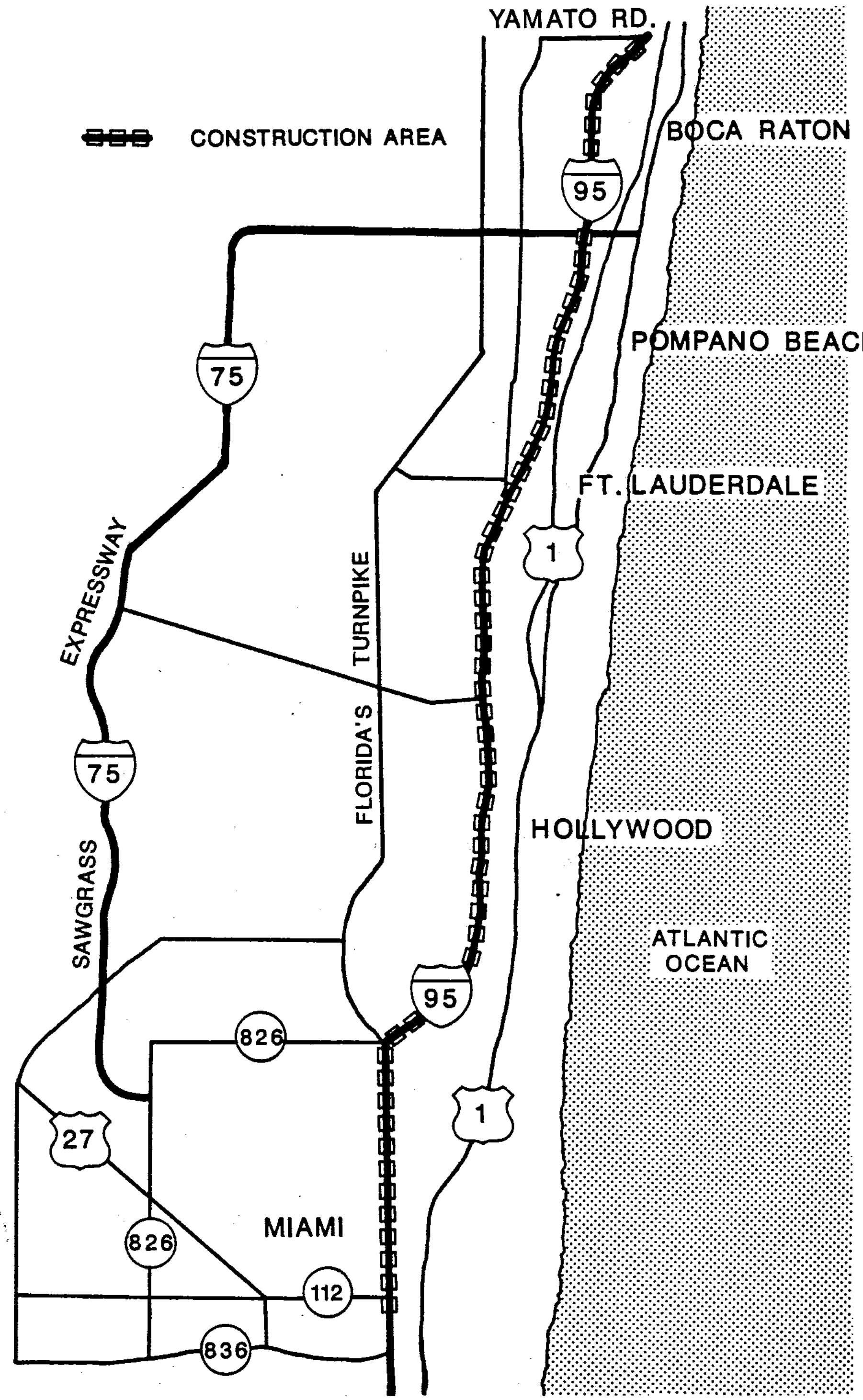
In recognition of the existing traffic congestion in the I-95 corridor and out of concern for the further degradation of traffic conditions during construction, the Florida Department of Transportation (FDOT) retained a private consulting firm to prepare a System Maintenance of Traffic (MOT) program to maintain safe and efficient traffic operations within the I-95 corridor (12).

Referring back to Figure A-22, the System MOT program covers an area bordered by Yamato Road to the north, US-1 to the east, SR 836 to the south, and the I-75 Sawgrass Expressway to the west. The objectives of the System MOT program were to: (1) maintain a reasonable level of service on a system-wide scale; (2) predict roadway capacity deficiencies before they occur, rather than reacting to congestion after it takes place; (3) coordinate activities among construction projects; (4) advise commuters of available alternative routes and modes of transportation during construction; and (5) encourage work zone safety for motorists and construction workers.

The basic TCP strategy during construction of I-95 involves only narrow lanes and shoulders. Temporary lane closures will be permitted only at night between 7 p.m. and 6 a.m. Two techniques are being used to maximize the capacity of the construction zone. These techniques are: (1) PCB with paddle screens within the construction zone to separate traffic from work activities, and (2) a freeway incident management program consisting of service patrols, accident investigation sites, and a motorist emergency telephone system.

Other components of the System MOT program includes:

1. Improvements on alternative routes,



Fiqure A-22. I-95 in Miami.

2. Travel demand management measures,

3. Transit improvements, and

4. Public information tools.

The improvements on alternative routes include both roadway and intersection improvements as well as implementation of an expanded computer-controlled traffic signal system. The Southeast Regional Planning Model, a network-based transportation planning model, was utilized to develop and evaluate potential improvements on alternative routes. Specifically, the model was used to: (1) predict capacity deficiencies along the regional roadway system; (2) assess individual traffic congestion mitigation measures; (3) assess alternative System MOT plans; (4) estimate system requirements including lane and intersection improvements; and (5) assess the impacts of construction schedule changes. The model was validated prior to use through an origin-destination survey, traffic counts, and travel time and delay studies.

Five alternative routes were selected for improvement based on the concentration of potential problem spots, potential contribution to the System MOT program, and diversification of improvements. These improvements included restriping, reversible lanes, traffic signal improvements, improved utilization of a one-way pair, roadway widening, channelization, peak period turn restrictions, intersection expansion, and signing improvements. Most of the improvements on alternative routes will be completed before the construction and widening of the I-95 main lanes begins early in 1989.

Two travel demand management measures were identified: (1) the implementation of a regional commuter ridesharing program, and (2) a program to encourage major employers to implement variable work hours. Ridesharing programs existed in individual communities along the corridor, but a new program was implemented to coordinate existing activities and to provide a region-wide matching service. A private transportation services management company was retained to provide the service. The same company also handles publicity and community relations for the entire I-95 project and provides coordination among all transportation agencies involved in the project.

The principal element of the transit package for I-95 is the Tri-Rail commuter rail service that will begin in January 1989. The commuter rail system in the Miami area has been under development for a number of years. However, the construction project was seen as a rare opportunity to provide a strong incentive to use the service. Consequently, FDOT made a concerted effort to time the start of rail service to coincide with the construction project.