Synthesis of Traffic Management Strategies for Urban Freeway Reconstruction Projects

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Managing traffic during an urban freeway reconstruction project is a significant and complex problem. Fortunately, the planning efforts for future projects can benefit from the traffic management experiences from a number of successfully completed reconstruction projects. This paper compiles the corridor traffic management strategies employed at a sample of eight projects in Chicago, Pittsburgh, Houston, Syracuse, Boston, Philadelphia, Detroit, and Minneapolis. The paper also summarizes the observed effectiveness of the various strategies. Corridor traffic management plans are divided into three components: (a) a traffic-handling strategy for the highway being reconstructed, (b) impact-mitigation strategies for alternative routes and modes, and (c) a public information program. The three basic traffic-handling strategies are minor capacity reductions, lane closures, and total roadway closures on the highway being reconstructed. There have been successful applications of all three traffic-handling strategies. Keys to successful traffic management during reconstruction have been a coordinated, corridorwide perspective for managing traffic and an effective public information program for advising motorists about the project, prevailing traffic conditions, and travel alternatives.

Managing traffic during the reconstruction of heavily traveled urban freeways is a significant and complex problem being faced by an increasing number of cities in the United States. In many cases, the solution to the problem requires a corridorwide perspective that extends beyond the highway being reconstructed to alternative routes and modes. In recognition of the problem, the Federal Highway Administration (FHWA), in cooperation with the Transportation Research Board, sponsored a National Conference on Corridor Traffic Management for Major Highway Reconstruction in the fall of 1986. Conference participants made the following recommendation:

> The many successful corridor traffic management plans prepared to date and the excellent results obtained with them should be synthesized for reference by all state and metropolitan transportation and planning agencies likely to face rebuilding of major highway facilities (*1*).

This paper provides such a synthesis.

The paper compiles the traffic management strategies employed at a sample of urban freeway reconstruction projects and summarizes available data on the effectiveness of the strategies. The eight projects reviewed and the years they were conducted are as follows:

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- Edens Expressway (I-94) in Chicago (1978–1980),
- Penn-Lincoln Parkway East (I-376) in Pittsburgh (1981–1982),
- Katy Freeway (I-10) in Houston (1983–1984),
- I-81 in Syracuse (1984),
- Southeast Expressway (I-93) in Boston (1984–1985),
- Schuylkill Expressway (I-76) in Philadelphia (1985–1989),
- John C. Lodge Freeway (US-10) in Detroit (1986–1987), and
- I-394 in Minneapolis (1985–1992).

SYNTHESIS OF TRAFFIC MANAGEMENT STRATEGIES

A corridorwide perspective for traffic management during reconstruction is implemented through a corridor traffic management plan. The three components of a corridor traffic management plan are as follows:

- A traffic-handling strategy for the highway being reconstructed,
- Impact-mitigation strategies for alternative routes and modes in the affected corridor, and
- A public information program.

The traffic-handling strategy addresses the accommodation of traffic in the reconstruction zone. Impact-mitigation strategies are transportation systems management actions to increase capacity and improve the level of service on alternative routes and modes. The public information program educates the public about the reconstruction project, prevailing traffic conditions, and travel alternatives. The three components are interrelated, but will be discussed in turn in the following sections.

Traffic-Handling Strategies

Traffic-handling strategies may be grouped into three general categories:

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

- Lane closures—the closure of some, but not all, lanes in one or both directions of the highway being reconstructed; and
- Total roadway closures—the closure of all lanes in one or both directions of the highway being reconstructed.

Table 1 summarizes the basic traffic-handling strategy used at the reconstruction projects. The following sections provide a brief description of how the strategies were applied in each project.

Minor Capacity Reductions

The projects in Houston (I-10), Boston (I-93), and Minneapolis (I-394) involved only minor capacity reductions through the reconstruction zone. In each case, it was determined that adequate work space could be developed without reducing the number of lanes available to traffic and that the cost required to do so was justified because the alternative routes and modes did not have sufficient unused capacity to accommodate significant traffic diversion from the reconstruction zone. Consequently, project planners and engineers developed construction-phasing sequences and traffic control plans that maintained as much capacity as possible on the highway being reconstructed.

The Katy Freeway (I-10) is a major Interstate highway between downtown Houston and its western suburbs. A reconstruction project was conducted during 1983–1984 to retrofit the freeway with a median transitway and to rehabilitate the pavement structure (*2*). The freeway cross section varied from six lanes at the western end of the project to eight lanes at the eastern end, with 1982 average annual daily traffic (AADT) varying from 135,000 to 186,000 vehicles per day (vpd). The project contract required that the number of lanes on the freeway during peak periods be the same during reconstruction as before reconstruction. 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 cross section with traffic routed around the work areas in narrow lanes (10 to 11 ft wide) with no shoulders on either side. Work areas and travel lanes were separated by portable concrete barriers. Because only minor capacity reductions were planned, no special impact mitigation or public information actions were taken.

TABLE 1 TRAFFIC HANDLING STRATEGY EMPLOYED AT A SAMPLE OF RECONSTRUCTION SITES

	Minor Capacity Reduction	Lane Closure	Total Roadway Closure
Houston	X		
Boston	X		
Minneapolis	X		
Chicago		X	
Pittsburgh		X	
Philadelphia		X	
Syracuse			X
Detroit			X

In Boston, the Southeast Expressway (I-93) is the only major highway facility connecting Boston with southeastern Massachusetts. The expressway is a six-lane freeway facility with a breakdown lane in each direction used as an additional travel lane during peak hours. It carried more than 160,000 vpd before reconstruction. An 8.5-mi section of the expressway was reconstructed during 1984 and 1985 (*3–5*). During reconstruction, 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. Thus, four travel lanes were provided for peak direction traffic, the same number as before reconstruction, and two lanes for off-peak direction traffic. Because there was no previous experience with such a traffic-handling strategy, there was considerable uncertainty about how effective it would be. Therefore, an extensive package of impact mitigation and public information actions was implemented to provide motorists a wide variety of alternatives in the event that severe congestion developed during reconstruction. The package was implemented with the flexibility to discontinue actions that proved unnecessary.

I-394 is a new segment of Interstate highway being built along the alignment of existing US-12, the principal arterial highway linking the western suburbs with downtown Minneapolis (*6*). The western portion of the 11-mi segment being reconstructed was a four-lane divided highway with several at-grade intersections, and the eastern portion was a six-lane freeway. I-394 will be a six-lane freeway with two reversible, high-occupancy vehicle (HOV) lanes. The AADT on US-12 in 1984 ranged from 49,000 vpd near the western end to 99,000 vpd at the maximum load point. During reconstruction, two through lanes of mixed traffic were maintained in each direction. To accomplish this, the project was divided into eight major segments that will be completed over an 8-yr period (1985–1992). Temporary detours and bypasses, some of which required additional signalized intersections, were provided at several locations to maintain two lanes on US-12 as well as to minimize the disruption to cross-street traffic. Therefore, even though the same number of travel lanes was maintained, some reduction in capacity was expected. A number of impact-mitigation strategies were implemented as part of the during-reconstruction component of the long-range Transportation Systems Management Plan for the I-394 corridor. The key strategy was an interim HOV lane in the median of the existing facility (*7,8*).

Analyses of the projects suggest that traffic volumes through the reconstruction zones were maintained at nearly the same levels as before reconstruction with little or no effect on operating conditions. Average speeds in Houston decreased by less than 3 mph during the morning peak period and actually increased during the afternoon peak period (*2*). In Boston, the use of the express lanes in the peak direction allowed traffic to travel at slightly higher speeds than before reconstruction; it was also estimated that 5,000 to 9,000 vpd (3 to percent of before-reconstruction volumes) diverted from I-93 during the first year of reconstruction, but that volumes returned to before-reconstruction levels during the second year (*4*). In Minneapolis, preliminary indications are that traffic volumes on I-394 are only slightly lower than before reconstruction.

Lane Closures

As indicated in Table 1, several reconstruction projects—Edens Expressway (I-94) in Chicago, Parkway East (I-376) in Pittsburgh, and Schuylkill Expressway (I-76) in Philadelphia—have required long-term lane closures. Due in large part to careful planning and implementation by project officials, the required reconstruction work was accomplished without causing massive congestion through the affected corridor. In most instances, substantial improvements to alternative routes and modes were made to accommodate the traffic diverting from the reconstruction zone.

The Edens Expressway (I-94) is a six-lane freeway that serves the north shore suburbs of Chicago. The AADT before reconstruction 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 3-yr reconstruction project was conducted on a 15-mi segment of the Edens Expressway from 1978 through 1980 (*9–12*). During reconstruction, one directional roadway of the expressway was closed at a time and four-lane two-way traffic was maintained on the other directional roadway, resulting in approximately a 33-percent reduction in freeway capacity. A portable concrete barrier separated two-way traffic. A 35-mph speed limit was established due to the reduced lane widths, restricted lateral clearances to the concrete barrier, proximity of reconstruction operations, low-speed temporary ramp connections, and frequent changes in ramp closures. To accommodate the traffic that was expected to divert from the freeway, a limited package of improvements to alternative routes and modes was implemented through cooperation with affected agencies.

The Penn-Lincoln Parkway East (I-376) 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. It carried 132,000 vpd through the rehabilitated section, including 80,000 vpd through the tunnel. The Pennsylvania Department of Transportation undertook a reconstruction and safety update project on a 6.5-mi section of the parkway during 1981–1982 (*13–15*). The Parkway East project was the first in which FHWA authorized the use of Interstate funds to mitigate the off-system impacts of Interstate reconstruction. The traffic-handling strategy employed during most of the project was to close one directional roadway (inbound in 1981 and outbound in 1982) and to maintain two-lane, two-way traffic on the other roadway. The entrance ramps within the reconstruction zone were closed, and the entrance ramps nearest each end of the reconstruction zone were restricted to HOVs. The closure of one direction of the freeway reduced its capacity by approximately 50 percent, and the ramp closures reduced access. As a result, many motorists were forced to divert. Since the only alternative routes were arterial streets, many of which were already congested, a package of impact mitigation and public information actions was implemented to improve alternative routes and modes of travel.

The Schuylkill Expressway (I-76) is the major east-west freeway connecting downtown Philadelphia with the Pennsylvania Turnpike (I-76) and western suburbs. The 21-mi long freeway is predominantly four lane, although several segments near downtown have six or eight lanes. Traffic volumes before reconstruction ranged from 80,000 vpd near the turnpike to 143,000 vpd near downtown. Reconstruction of an 18-mi segment of the expressway began in 1985 and was scheduled for completion in 1989 (*16–18*). Two lanes of traffic are being reconstructed 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 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 to 60 percent reduction in capacity. Since no major parallel alternative routes existed, the traffic management plan was designed to enable trucks, visitors, and long-distance travelers to remain on the expressway and to encourage short-distance, local drivers to divert from the expressway. A key to diverting traffic was the closure of most of the entrance ramps and some of the exit ramps within or leading to the reconstruction zone. Improvements were made to alternative routes and modes to accommodate the diverted local traffic, and an extensive public information program was implemented to educate motorists about the project and the travel alternatives.

Significant traffic volume reductions were observed at the Chicago, Pittsburgh, and Philadelphia reconstruction zones. In Chicago, the AADT was approximately 30 percent less during reconstruction, and peak period volumes decreased by nearly 35 percent. In Pittsburgh, a 60-percent reduction in daily traffic volumes was observed. The results in Philadelphia, although not yet fully documented, indicate a 50 to 60-percent reduction in AADTs through the reconstruction zone. The most common motorist response was diversion to an alternative route. Some shifting in departure times, which spread out the peak periods, was also observed. In Pittsburgh, for example, departure times during reconstruction averaged 20 min earlier than before reconstruction. The use of mass transit and ridesharing modes was heavily promoted but accounted for only a small portion of traffic diverted. In Chicago, no increase in mass transit was observed during reconstruction. In Pittsburgh, only 5 percent of the peak period traffic that diverted was traced to alternative modes. Officials in Philadelphia reported moderate increases in transit usage and ridesharing. An overall assessment of these reconstruction projects indicates that the reconstruction was accomplished within a reasonable period of time, that the impacts on motorists were minimized to the extent possible, and that the inconveniences and delays that did occur were well tolerated by the public.

Total Roadway Closure

Two recent freeway reconstruction projects have involved total roadway closures. The reconstruction projects on both

I-81 in Syracuse and the Lodge Freeway (US-10) in Detroit employed total closures of one direction of the freeway.

I-81 is the major north-south freeway running through Syracuse, New York. Traffic on the four-lane freeway had reached 70,000 vpd by the 1970s and was approaching capacity. Therefore, in the late 1970s the New York Department of Transportation initiated a reconstruction project to add two travel lanes on a 10-mi segment of the Interstate and to modernize three major interchanges (*19, 20*). Throughout most of the project, the basic traffic-handling strategy was minor capacity reductions. 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 on I-81 through the I-690 interchange. It was also necessary to close one northbound lane and slow traffic on the remaining northbound lane to 30 mph to minimize damaging vibrations in the southbound structure. Improvements on alternative routes and modes and an extensive public information program were implemented to mitigate the impacts of the freeway closure.

The Lodge Freeway is a six-lane freeway connecting downtown Detroit and its northwestern suburbs. AADTs prior to reconstruction were approximately 125,000 vpd at the maximum load point. The Michigan Department of Transportation undertook a 2-yr project to reconstruct an 8.4-mi section of the freeway during 1986 and 1987 (*21, 22*). Because considerable unused capacity existed on nearby parallel freeways and arterial streets, the traffic-handling strategy adopted was the total closure of one directional roadway at a time with traffic diverted to designated alternative routes. The traffic management plan involved staging the project over two construction seasons. In 1986, the work did not directly involve the travel lanes and therefore the freeway capacity reductions were minor. The traffic management plan for 1987 involved directional closures with one-way traffic maintained in the open direction. The northbound (outbound) lanes were closed from April through July 1987, and the southbound (inbound) lanes were closed from July through October 1987. Traffic in the closed direction was diverted to alternative routes and modes. An extensive public information program disseminated information on the travel alternatives during reconstruction.

At both projects, the most common motorist response was to use alternative routes in the corridor. The HOV measures that were initiated or expanded during reconstruction attracted little or no increase in ridership, due largely to the availability of unused capacity on the alternative routes and to the lack of a travel time advantage for HOV modes. The public information programs were considered vital to the success of the traffic management plans for both projects. Travel times in the corridor increased, but motorists were well aware of the project, why it was important, and what travel alternatives were available. As a result, the inconveniences were well tolerated and the overall public response was positive.

Techniques to Maximize the Capacity of the Reconstruction Zone

In conjunction with the basic traffic-handling strategy, a number of techniques have been employed to maximize the capacity of the reconstruction zone including the following:

- Using portable concrete barriers to separate the travel lanes from work areas or to separate opposing lanes of traffic;
- Widening and upgrading shoulders for use as temporary travel lanes;
- Using exclusive, reversible lanes for peak-period, peak-direction through or HOV traffic;
- Closing ramps or restricting ramps to HOVs; and
- Implementing incident management techniques to reduce incident detection and response time.

Table 2 summarizes the techniques used at each of the reconstruction projects reviewed. Limited data are available on the effectiveness of the individual strategies, because at most projects several techniques were used in combination and it is impossible to separate the impacts of each technique.

The combination of techniques used in Houston (portable concrete barriers, ramp closures, and temporary shoulder lanes)

TABLE 2 TECHNIQUES EMPLOYED AT A SAMPLE OF PROJECTS TO MAXIMIZE THE CAPACITY OF THE RECONSTRUCTION ZONE

	Portable Concrete Barriers	Ramp Closures/ Restrictions	Temporary Shoulder Lanes	Reversible Lanes	Incident Management Techniques
Houston	X	X	X		
Boston	X	X	X	X	X
Minneapolis	X			X	
Chicago	X	X	X		X
Pittsburgh	X	X	X		X
Philadelphia	X	X	X		X
Syracuse	X	X			
Detroit	X	X			X

allowed traffic to move through the reconstruction zone only slightly impeded (*2*). Peak period capacities averaged 1,750 vehicles per hour per lane (vphpl), which is higher than would be predicted by the 1985 *Highway Capacity Manual* (*23*) for a six-lane freeway with 10- to 11-ft lanes and no shoulders.

The impacts of utilizing shoulders as temporary travel lanes through the reconstruction zone have not been documented. However, the safety effects of shoulder removal to add travel lanes under normal urban freeway conditions have been investigated. Recent results suggest that converting the inside shoulder to a travel lane does not appreciably increase accident frequencies and may, in fact, decrease them significantly on high-volume facilities (*24–26*). Available data on converting an outside shoulder to a travel lane indicate a slight increase in accident rates. The results suggest that using the inside shoulder as a travel lane during reconstruction may be effective, but that outside shoulder removal, either alone or in conjunction with inside shoulder removal, may not be justified due to potential increases in accidents and delays during incidents.

Reversible express lanes for through traffic proved effective in Boston, where peak-period travel times on the freeway were the same or lower than before reconstruction even though little traffic diverted from the freeway. Separating through traffic from the merging and diverging maneuvers of local traffic streamlined traffic flow and was a key to the successful traffic management plan.

Ramp closures or restrictions to HOVs only reduce traffic demands on the freeway and may increase capacity by reducing merging conflicts. The costs of implementing ramp closures, which involve primarily signing and barricades, are minimal. The principal costs of ramp restrictions to HOV usage are for enforcement. During the Parkway East reconstruction in Pittsburgh, signing and enforcement of two HOV-only ramps cost $750 per day (in 1987 dollars) (*13*). The HOV ramps were located at the beginning of the reconstruction zone and enabled HOV users to bypass much of the congestion that developed upstream of the reconstruction zone. It was estimated that the ramps saved HOV users an average of 8 min per person-trip, which translated into a benefit-to-cost ratio of 31:1. Impacts on mixed flow traffic were reported to be minimal.

Incident management techniques during reconstruction have included additional police or courtesy patrols and free tow-truck service. Several projects have provided free tow-truck service to reduce incident response time and thereby minimize incident-related delays. Data regarding the costs and usage of the free tow-truck service in Boston and Detroit indicate that the cost per vehicle serviced was approximately $150 and $200, respectively. The number of calls handled per day is a function of both the amount of traffic on the freeway and the number of tow trucks provided. Unfortunately, data regarding the benefits of the service in terms of reduced motorist delay and accident potential have not been documented. However, the potential incident-related delays are considerable, particularly when lanes are narrowed and one or both shoulders are eliminated within the reconstruction zone.

Impact-Mitigation Strategies

Impact-mitigation strategies have consisted primarily of transportation systems management improvements to increase capacity or improve the level of service on alternative routes and modes of travel. The following sections summarize the actions that have been employed.

Improvements to Alternative Routes

In anticipation of large volumes of traffic diverting to alternative routes, impact-mitigation measures on arterial streets in the affected corridor have been implemented as part of several reconstruction projects. These improvements have included the following:

- Traffic signal improvements,
- Other intersection improvements, and
- Other roadway improvements.

Table 3 summarizes the types of improvements made at the eight projects reviewed in this paper. It is difficult to isolate the effectiveness of the individual strategies because at most projects a coordinated package of improvements was implemented.

Traffic signal improvements have included the following:

- Adjustments in signal phasing and timing;
- Improvements in signal equipment—installation of temporary traffic signals, traffic-actuated signals, time-based coordination, and computerized traffic signal control systems; and
- Deactivating signals.

The benefits of adjustments in signal timing in a reconstruction context have not been documented. However, these actions are likely to be cost-effective because the cost is low and the potential savings in travel time are significant. Although not in a reconstruction context, experiences from a recent signal retiming program in North Carolina provide an indication of the cost effectiveness of signal timing improvements. Signals were retimed at an average cost of $481 per intersection, and the benefit-to-cost ratio was 108:1 (*27*). Improvements in signal equipment are more costly, but their benefits extend beyond the reconstruction period, a fact that should be considered in cost-effectiveness evaluations. In Syracuse, signals at two intersections were deactivated during reconstruction to improve operations on an important alternative route (*20*).

Other intersection improvements have included the following:

- Temporary left-turn prohibitions;
- Parking restrictions;
- Improved signing, lighting, and pavement markings;
- Police officer control during peak periods;
- Intersection channelization; and
- Intersection widening.

Turn prohibitions, parking restrictions, and improvements in signing, lighting, and markings are relatively inexpensive but can yield valuable operational benefits. Police control is a flexible strategy that has been useful primarily at the beginning of projects while motorists are adjusting their travel patterns. However, the cost of police control is relatively high. In Pittsburgh, for example, police control of 17 signalized intersections during peak periods cost more than $17,600 per

TABLE 3 IMPROVEMENTS MADE ON ALTERNATIVE ROUTES AT A SAMPLE OF RECONSTRUCTION PROJECTS

	Traffic Signal Improvements	Other Intersection Improvements	Other Roadway Improvements
Houston			
Boston	X	X	X
Minneapolis	X	X	X
Chicago			
Pittsburgh	X	X	X
Philadelphia	X	X	X
Syracuse	X	X	X
Detroit	X	X	X

week (in 1987 dollars) for a total cost of $633,000 for the 2-yr project (*13*). In Boston, police control at key locations was budgeted at $438,000 (in 1987 dollars) for the 2-yr project (*5*). In both Pittsburgh and Boston, the number of locations at which police were used was reduced dramatically within 1 month after the beginning of the projects because most of the problems anticipated never materialized. Intersection channelization or widening to add turning lanes is more costly but can provide valuable, permanent increases in capacity.

Other roadway improvements have included the following:

- Reversible lane on an arterial street,
- Converting streets to one-way pairs,
- Pavement marking changes to add additional travel lanes,
- Midblock parking prohibitions,
- Pavement surface improvements, and
- Signing and lighting improvements.

These actions are relatively easy-to-implement operational improvements. Although no data isolating the benefits of these improvements are available, their cost is low enough that the probability of their being cost-effective is high.

Overall, improvements to alternative routes have been worthwhile impact-mitigation actions. For those projects where significant diversion occurred, most of the diverted traffic was traced to alternative routes in the corridor. The improvements implemented helped reduce the impact of these traffic increases on the alternative routes. Many of the improvements were permanent and continued to provide improved traffic operations after the reconstruction project was completed. In Pittsburgh and Detroit, alternative routes in the affected corridor were forced to handle large volumes of diverted traffic. Despite the significant increases in traffic, corridorwide travel times in Pittsburgh were only 16 percent longer during the morning peak and 57 percent longer during the evening peak (*14*). Motorists adjusted to these longer times by departing 20 min earlier during reconstruction (*13*). In Detroit, approximately 60,000 vpd were diverted to alternative routes; travel times increased approximately 33 percent on the alternative freeway route but did not change significantly on most of the alternative arterial routes, due in large part to the signal coordination efforts on those routes (*22*).

Improvements to Alternative Modes

At most of the reconstruction projects reviewed, improvements were made to alternative modes of travel in an attempt to reduce traffic volumes through the reconstruction zone by diverting motorists to mass transit or HOVs. Improvements in public transportation and other HOV modes have included the following:

- Expanded bus service—new express bus service, increasing feeder service to commuter rail or rapid transit stations, adding buses to maintain or increase prereconstruction headways, and placing backup buses on call in case of delays;
- New or expanded rail service—new commuter rail service, expanded rail rapid transit service, adding cars to existing trains, extending rail service beyond the existing terminus, and adding trains to increase service frequency;
- Expanded commuter boat service;
- New or expanded park-and-ride lots; and
- Expanded ridesharing programs.

Table 4 summarizes the improvements implemented at the projects reviewed. Expanded bus service, ridesharing programs, and park-and-ride lots were the most widely used strategies. Rail service improvements were made in Boston, Pittsburgh, and Philadelphia. In Boston, the commuter boat service was also expanded.

At most of the projects, the improvements did not produce substantial increases in transit ridership or ridesharing. Little or no increases were reported in Chicago, Syracuse, and Detroit. The limited documentation available from Philadelphia suggests that some increase in rail ridership (1,300 person-trips per day) and requests for ridesharing matches (3,200 during the first year) occurred during reconstruction.

The most detailed documentation is available for the projects in Pittsburgh and Boston. In Pittsburgh, the new com-

TABLE 4 IMPROVEMENTS MADE TO HOV AND PUBLIC TRANSPORTATION SERVICES AT SELECTED RECONSTRUCTION PROJECTS

	Expanded Bus Service	New or Expanded Rail Service	Expanded Boat Service	New or Expanded Park-and-Ride Lots	Expanded Ridesharing Programs
Houston					
Boston	X	X	X	X	X
Minneapolis	X			X	X
Chicago	X			X	X
Pittsburgh	X	X		X	X
Philadelphia	X	X		X	X
Syracuse	X			X	X
Detroit	X				X

muter rail service attracted 500 person-trips per day at a cost of $25 per trip (in 1987 dollars); the express bus service attracted 1,500 new person-trips per day at a cost of $5 per trip; and the expanded vanpool promotion efforts produced 750 new person-trips by vanpool at a cost of only $0.20 per trip. In Boston, the improvements to commuter rail service attracted 400 person-trips per day at a cost of $20 per trip; the rail rapid transit improvements attracted 850 person-trips per day at a cost of $2.50 per trip; the expanded commuter boat service attracted 200 person-trips per day at a cost of $12 per trip; and the expanded efforts to promote vanpooling attracted 140 person-trips per day at a cost of $3.00 per trip. Express bus ridership actually decreased in Boston in spite of a more than $1 million investment in expanded service.

In Minneapolis, the interim reversible HOV lane implemented during reconstruction of I-394 attracted 2,000 vpd, which represented about 5,400 person-trips per day. However, some of these HOVs were attracted from other routes due to travel time savings on the HOV lane. Hence, the cost of the interim HOV lane was approximately $1.30 per person-trip diverted from the mixed flow lanes in the reconstruction zone.

Public Information Programs

A critical factor in the success of the traffic management plans for the projects reviewed has been an extensive public information program. These programs helped create a positive, cooperative atmosphere in the affected communities by keeping motorists and public and private agencies apprised of conditions through the reconstruction zone and of travel alternatives.

Public information techniques have included the following:

- Traditional public relations tools—press conferences, media events, press tours, public meetings, press kits, news releases, interviews, paid advertising, and public service announcements;
- Special publications—posters, pamphlets, newsletters, maps, utility bill inserts, and other mailings;
- Toll-free hotlines;
- Special signing—changeable message signs, billboards;
- Highway advisory radio; and
- Ombudsman.

Table 5 summarizes the elements of the public information programs for the reconstruction projects reviewed in this paper. Although it is difficult to quantify its benefits, a public information program is vital to the success of a traffic management plan. Three important elements of the programs have been the efforts to (a) keep the public informed of the conditions through the reconstruction zone and of the availability of travel alternatives, (b) coordinate the actions of all public agencies involved in the project, and (c) maintain communications with public and private groups affected by the project. Perhaps the best indications of the effectiveness of the public information programs have been (a) the lack of congestion at the beginning of most projects because drivers heeded the responsible agency's advice to avoid the reconstruction zone and (b) the generally positive public attitude about the projects and the agencies involved.

SUMMARY OF EXPERIENCES AND OBSERVED STRATEGY EFFECTIVENESS

The experiences from the projects reviewed demonstrate that major urban freeway reconstruction can be conducted without intolerable disruptions in corridor traffic flow. The traffic management and impact-mitigation strategies deserve much of the credit for these successes. Latent capacity in the corridor and the ingenuity of motorists in selecting optimal routes also contributed to the fact that the regional transportation networks were able to accommodate the freeway capacity reductions with less congestion and delay than project planners had predicted.

TABLE 5 PUBLIC INFORMATION TECHNIQUES EMPLOYED AT SELECTED RECONSTRUCTION PROJECTS

	Traditional Public Relations Tools	Special Publications	Toll-Free Hotlines	Special Signing	Highway Advisory Radio	Ombudsman
Houston	X			X		
Boston	X	X	X	X	X	
Minneapolis	X	X	X	X		
Chicago	X			X	X	
Pittsburgh	X	X	X	X		
Philadelphia	X	X	X	X		
Syracuse	X	X		X		
Detroit	X	X	X	X		X

Motorists have five options for responding to the impacts of reconstruction projects:

- Cancellation of trips in the corridor;
- Spatial diversion (i.e., continue to travel in the corridor by the same mode but on a different route);
- Temporal diversion (i.e., continue to travel in the corridor by the same mode and route but at a different time);
- Modal diversion (i.e., continue to travel in the corridor but by a different mode); and
- Continuation of normal travel patterns.

Most motorists who changed their travel patterns continued to drive their automobiles in the corridor but either diverted to another route (spatial diversion) or changed their departure times (temporal diversion). Some motorists changed their mode of travel, but the numbers were not large. Few motorists canceled trips in the corridor.

Traffic diverted to many different routes. In Pittsburgh, where local traffic was forced to divert because entrance ramps were closed, diverting traffic was traced to many alternative routes but most was concentrated on the parallel arterial routes closest to the freeway. The experiences at the other projects were similar.

Motorists shifted back and forth between the freeway and alternative routes during the first several weeks of the projects, apparently experimenting with alternative routes before selecting their preferred route. In some cases, predictions of chaos by the press may have scared motorists away, but when the chaos failed to materialize the motorists returned to the freeway. After several weeks, an equilibrium was established. However, fluctuations continued. Throughout the projects, motorists shifted back and forth between the freeway and their alternative route as traffic conditions changed.

Temporal diversion was also observed. Motorists in Pittsburgh and Boston adjusted their departure times, especially in the morning, to compensate for the increased travel times in the corridor. In Pittsburgh, for example, morning departure times during reconstruction averaged 20 min earlier than before reconstruction.

Some modal diversion to HOV modes occurred, but the magnitude was much less than project planners had anticipated. In Pittsburgh, for example, only 5 percent of the peak-period traffic that diverted was traced to alternative modes. Officials in Chicago and Detroit reported little or no change in transit ridership. In both Detroit and Boston, much of the additional bus service provided initially was discontinued because it had not attracted sufficient ridership. It appears that the reconstruction projects reviewed did not cause significant enough changes in relative modal costs or travel times to change the long-held modal decisions of large numbers of commuters.

Importantly, at all of the projects reviewed there was little, if any, reduction in the total corridor daily traffic volumes. In Pittsburgh, for example, traffic volumes along a complete screenline through the affected corridor near the center of the reconstruction zone decreased by only 1.5 percent during the first construction season in spite of a 60-percent reduction in traffic on the Parkway East. Except for indications at the projects in Chicago and Boston that some discretionary, midday, nonwork trips were eliminated from the corridor, it appears that few vehicle trips were actually canceled.

In light of the motorist impacts observed, it is apparent that the improvements on alternative routes were the most cost-effective component of the impact-mitigation strategies. The improvements in HOV services were less cost-effective in terms of the cost per trip diverted. However, some investment in alternative modes was generally considered necessary to provide flexibility to the motorist and to allow for the margin of error in project planning analyses. The evidence suggests that improvements to existing services were more effective than the provision of new services, such as the new commuter train in Pittsburgh, which was discontinued near the end of the first year of reconstruction. The flexibility to discontinue lightly used services is desirable in implementing improvements in HOV services.

The public information programs were considered vital to the success of the projects. They helped prevent strong negative public reaction. More than that, they helped promote reasonably positive reactions that (a) the work was necessary for the long-term good and (b) the agencies involved were doing their best to complete the project with the least inconvenience possible.

Overall, past experiences suggest that a well-planned, -coordinated, -implemented, and -communicated traffic management plan can effectively limit the disruption in corridor traffic flow during urban freeway reconstruction projects. There have been successful applications of all three basic traffic-handling strategies (minor capacity reductions, lane closures, and total roadway closures) in conjunction with appropriate impact-mitigation strategies and public information programs. Good information and sound analysis are vital to the design of an effective strategy. Also vital are (a) the ability to evaluate unexpected impacts quickly and (b) the flexibility to alter strategies accordingly. The lessons that can be learned from successfully completed projects are valuable and merit careful study.

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REFERENCES

1. *Special Report 212: Transportation Management for Major Highway Reconstruction*. TRB, National Research Council, Washington, D.C., 1987.
2. N. M. Kuo and J. M. Mounce. Operational and Safety Impacts on Freeway Traffic of High-Occupancy Vehicle Lane Construction in the Median. In *Transportation Research Record 1035*, TRB, National Research Council, Washington, D.C., 1985, pp. 58–65.
3. Traffic Reroute. *Civil Engineering*, Vol. 54, No. 7, 1984, pp. 37–39.
4. W. T. Steffens, S. Weinstock, and M. E. Sullivan. *Corridor Transportation Management for Highway Reconstruction: Southeast Expressway, Massachusetts 1984–1985*. Report No. DOT-I-86-35. Massachusetts Department of Public Works, Boston, 1986.
5. M. D. Meyer. Reconstructing Major Transportation Facilities: The Case of Boston's Southeast Expressway. In *Transportation Research Record 1021*, TRB, National Research Council, Washington, D.C., 1985, pp. 1–9.
6. D. R. Eyler, C. Z. Beltt, and R. D. Borson. The I-394 Interim HOV Lane: A Valuable Construction Zone Traffic Management System. *Compendium of Technical Papers*, Institute of Transportation Engineers, Washington, D.C., 1986.
7. Strgar-Roscoe-Fausch, Inc. *Transportation Systems Management Plan: Interstate-394*. Final Report. Minnesota Department of Transportation, Minneapolis, 1986.
8. Strgar-Roscoe-Fausch, Inc. *I-394 Interim HOV Lane: A Case Study*. Phase I Report. Minnesota Department of Transportation, Minneapolis, 1987.
9. S. C. Ziejewski. Traffic Planning for Edens Reconstruction Project. *Journal of Transportation Engineering*, Vol. 109, No. 1, 1983, pp. 159–171.
10. H. M. Yamanaka. Social and Environmental Impacts: Edens Project. *Journal of Transportation Engineering*, Vol. 109, No. 5, 1983, pp. 721–732.
11. R. C. Wehner. *Eisenhower Expressway Rehabilitation versus Edens Expressway Reconstruction: A Comparative Analysis*. Illinois Department of Transportation, Division of Highways, District 1, Schaumburg.
12. C. B. McLean. The Edens Reconstruction Project. *Transportation Research News*, No. 94, 1981, pp. 9–13.
13. R. B. Anderson, C. T. Hendrickson, B. Janson, D. F. Kundrat, and L. R. Taylor. *Study of Alternative Transportation Strategies During Reconstruction of the Parkway East, I-376, Pittsburgh, Pennsylvania*. Report No. 81-118. GAI Consultants, Inc., Monroeville, Penn., and Carnegie-Mellon University, Pittsburgh, Penn., 1983.
14. C. T. Hendrickson, R. E. Carrier, T. J. Dubyak, and R. B. Anderson. Travel Responses to Reconstruction of Parkway East (I-376) in Pittsburgh. In *Transportation Research Record 890*, TRB, National Research Council, Washington, D.C., 1982, pp. 33–39.
15. Reconstruction Demands Traffic Control Savvy. *Engineering News Record*, September 19, 1985, pp. 52–53.
16. W. Eichorn and L. M. Morasco. *Special Report 212: Philadelphia, Schuylkill Expressway: Transportation Management for Major Highway Reconstruction*. TRB, National Research Council, Washington, D.C., 1987.
17. J. L. Greene and R. M. Rodgers. Traffic Management Plan for the Reconstruction of the Schuylkill Expressway. *Compendium of Technical Papers*, Institute of Transportation Engineers, Washington, D.C., 1984.
18. Space, Deadlines Tight on Highway Reconstruction. *Engineering News Record*, October 3, 1985, p. 34.
19. R. N. Simberg. *Special Report 212: Syracuse, Interstate 81: Transportation Management for Major Highway Reconstruction*. TRB, National Research Council, Washington, D.C., 1987.
20. A. J. Neveu and L. Maynus. *How to Manage Traffic During Highway Reconstruction*. New York State Department of Transportation, Albany, 1985.
21. P. Scott. The New Lodge. *Corridor Traffic Management for Major Highway Reconstruction: A Compilation of Case Studies*. FHWA, U.S. Department of Transportation, 1986.
22. R. R. Tadi, M. F. Kobran, and R. J. Bremer. Impact of the Lodge Freeway Reconstruction Closure on Surface Streets in Detroit. *ITE Journal*, Vol. 58, No. 9, 1988, pp. 27–32.
23. *Special Report 209: Highway Capacity Manual*. TRB, National Research Council, Washington, D.C., 1985.
24. W. R. McCasland. *The Use of Freeway Shoulders to Increase Capacity*. Report No. FHWA/TX-78-210-2. Texas Transportation Institute, College Station, 1978.
25. T. Urbanik and C. R. Bonilla. *Safety and Operational Evaluation of Shoulders on Urban Freeways*. Report No. FHWA/TX-87/32+395-1. Texas Transportation Institute, College Station, 1987.
26. T. Urbanik and C. R. Bonilla. California Experience with Inside Shoulder Removal. In *Transportation Research Record 1122*, TRB, National Research Council, Washington, D.C., 1987, pp. 37–46.
27. 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.

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