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16. Abstract <p>Accommodating traffic during the reconstruction of heavily traveled urban freeways is a challenging problem. This report provides guidelines for analyzing the potential corridor-wide travel impacts of urban freeway reconstruction projects and developing a corridor traffic management plan to mitigate those impacts. The focus is on the impact of a reconstruction project on traffic patterns and conditions in the freeway corridor and on the traffic management techniques that might be incorporated into a corridor traffic management plan to mitigate the adverse impacts. A catalog of the traffic-control options and traffic management techniques that might be incorporated in the plan is presented. A corridor analysis methodology is outlined for identifying, evaluating, and selecting those options and techniques that would be appropriate and effective for a particular project. Examples from a demonstration study in which the methodology was applied to the US-59 Southwest Freeway reconstruction project are presented to illustrate the use of the methodology.</p>			
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**CORRIDOR TRAFFIC MANAGEMENT PLANNING GUIDELINES
FOR MAJOR URBAN FREEWAY RECONSTRUCTION**

by

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and

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Research Report 1188-4F
Research Study Number 2-18-88-1188

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College Station, TX 77843

February 1991

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	2.54	centimetres	cm
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	centimetres squared	cm 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 m³.

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C
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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	hectares (10 000 m ²)	2.53	acres	ac

MASS (weight)

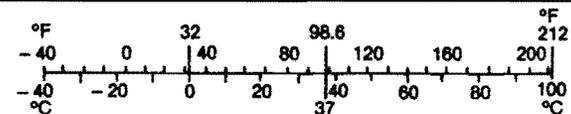
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

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

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F
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These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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SUMMARY

This report is the fourth and final report of Study Number 2-18-88-1188, "Corridor Analysis for Reconstruction Activities, Traffic Control Strategies, and Incident Management Techniques." The previous reports on the study are as follows:

Report 1188-1 "Synthesis of Traffic Management Techniques for Major Urban Freeway Reconstruction"

Report 1188-2 "Development of Expert Systems for Freeway Incident Management: Literature Review"

Report 1188-3 "Development of Expert Systems for Freeway Incident Management: Microcomputer User's Guide"

This report provides guidelines for analyzing the potential corridor-wide travel impacts of urban freeway reconstruction projects and developing a corridor traffic management plan to mitigate those impacts. The focus is on how a reconstruction project affects traffic patterns and conditions in the freeway corridor and on what traffic management techniques should be incorporated into a corridor traffic management plan to supplement the construction zone traffic control 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 three components of a corridor traffic management plan are:

1. The construction zone traffic control plan,
2. Corridor-wide impact mitigation techniques, and
3. A public information program.

The traffic control plan details how traffic will be accommodated in the construction zone. Impact mitigation techniques include improvements to increase capacity and improve the quality of service on alternative routes and modes of travel in the freeway corridor. The public information program advises motorists of traffic conditions and travel alternatives in the corridor during the reconstruction project.

A catalog of the traffic-control options and traffic management techniques that might be incorporated in the plan is presented. The three basic traffic-control options for the construction zone are: (1) maintain the same number of lanes as existed before construction, (2) long-term lane closures, and (3) total freeway closures. Traffic management techniques to facilitate traffic flow through the construction zone are described. Techniques to mitigate the adverse travel impacts throughout the corridor are

also discussed. These techniques include: (1) improvements to alternative routes, and (2) techniques to increase public transit ridership and ridesharing.

A corridor analysis methodology is presented for identifying, evaluating, and selecting those options and techniques that would be appropriate and effective for a particular project. Examples from a demonstration study in which the methodology was applied to the US-59 Southwest Freeway reconstruction project are presented to illustrate the use of the methodology.

IMPLEMENTATION STATEMENT

Texas is in the midst of an era in which many of the freeways in the urban areas of the state will be reconstructed. The SDHPT has been very sensitive to and successful at minimizing the travel impacts associated with reconstruction projects. Unfortunately, many projects in the future will involve even higher traffic volumes and more restricted right-of-way than past projects. Therefore, this report, which compiles experiences from past projects into a format useful to future project planning efforts, is very timely. Guidelines are presented for analyzing the potential corridor-wide travel impacts of urban freeway reconstruction projects and developing a corridor traffic management plan for mitigating the adverse impacts. A catalog of traffic-control options and traffic management techniques that might be incorporated into the plan is presented. A corridor analysis methodology is outlined for identifying, evaluating, and selecting those options and techniques that would be appropriate and effective for a particular project. These guidelines are designed for use by those planning, design, construction, and traffic engineers in the SDHPT districts who are charged with developing the sequence of construction, traffic control plans, and corridor traffic management strategies for urban freeway reconstruction projects.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas State Department of Highways and Public Transportation.

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1. INTRODUCTION

Accommodating traffic during the reconstruction of heavily traveled urban freeways is a challenging problem. The Texas State Department of Highways and Public Transportation (SDHPT) has been sensitive to the needs of motorists and has been successful at minimizing the adverse impacts on traffic. At most projects, the SDHPT has been able to maintain the same number of lanes through the work zone as were available prior to reconstruction and to restrict lane closures to off-peak travel periods only. Comparisons of traffic patterns and conditions before and during five such projects in Texas indicate that their impact has generally been minor. Some impacts have been observed, however, not only on the freeway but also on alternative routes in the corridor (1). Thus, even when the same number of lanes is maintained through the construction zone, reductions in capacity due to reduced lane and/or shoulder widths, ramp closures, and frontage road lane closures may be sufficient to change traffic patterns and conditions throughout the corridor. These changes should be considered in the planning process.

Furthermore, the SDHPT will not be able to maintain the same number of lanes during all urban freeway reconstruction projects. The North Central Expressway project in Dallas is a prime example in which the nature of the construction activity makes it virtually impossible to avoid long-term lane closures. On heavily traveled freeways, long-term lane closures have the potential of causing significant disruptions in traffic flow throughout an entire freeway corridor. The development of a corridor-wide traffic management plan in those cases is essential.

Future urban freeway reconstruction projects are likely to be even more challenging than in the past. Fortunately, many freeway reconstruction projects in Texas and elsewhere throughout the United States have been successfully completed. Credit for these successes goes to sound construction practices, innovative corridor-wide traffic management plans, effective public information programs, and resourceful, cooperative motorists. Therefore, it is now an appropriate time to take stock of the experiences gained and lessons learned from previous projects. This report compiles the experiences from these projects into a framework that will be useful in planning future urban freeway reconstruction projects.

PROBLEM STATEMENT

During urban freeway reconstruction projects, roadway space must be divided between the required construction activities and the motoring public. The basic problem in planning projects is to determine the best allocation and use of the limited available roadway space.

The way in which roadway space is used has significant cost implications. The best allocation and use is the one that minimizes the total cost of the project. It must be remembered that the SDHPT itself is not the only entity that bears costs. Motorists and

neighboring communities also bear costs associated with freeway reconstruction projects. The total cost of a project may be divided into three categories:

- o The costs borne directly by the SDHPT, including the cost of developing the plans for the project, the cost of actually performing the work, and the cost of administering contracts and inspecting the work.
- o The additional road user costs borne by motorists throughout the affected corridor, including increased travel-time, vehicle-operating, and accident costs that result from reductions in traffic-handling capacity and changes in roadway geometry.
- o The social, economic, and environmental costs borne by neighboring businesses and residents.

All three cost categories must be accounted for. The SDHPT has established procedures for estimating the costs it bears directly and, therefore, those procedures will not be restated in this report. Instead, the focus is on the traffic-related impacts and how to give due consideration to the associated additional road user costs in planning reconstruction projects. The last category of costs is difficult to quantify but is important nonetheless. Social, economic, and environmental costs result in part from the very presence of construction activity (e.g., the noise and dust produced from excavation work) and in part from the change in traffic patterns and conditions on the freeway and throughout the corridor (e.g., the additional air pollution resulting from the increase in congestion levels throughout the corridor). Generally, the social, economic, and environmental costs borne by neighboring businesses and residents can be reduced if the traffic impacts can be reduced.

SCOPE AND OBJECTIVES

This report is directed toward those planning, design, construction, and traffic engineers in the SDHPT districts who are charged with developing the sequence of construction, traffic control plans, and corridor traffic management strategies for urban freeway reconstruction projects. The objective is to provide these engineers with guidelines on how to give due consideration to the potential corridor-wide travel impacts of a freeway reconstruction project during the planning process.

ORGANIZATION OF THE REPORT

The main body of this report is divided into two sections. Chapter 2 describes the components of a corridor traffic management plan for dealing with the corridor-wide impacts of urban freeway reconstruction projects. Chapter 3 outlines a corridor analysis methodology for developing such a plan.

2. CORRIDOR TRAFFIC MANAGEMENT PLAN

When planning reconstruction projects on heavily traveled urban freeways consideration should be given to the traffic impacts not only on the freeway itself but also throughout the entire freeway corridor (which includes the frontage roads and surface streets that serve traffic between the same origins and destinations). The severity and extent of the traffic impacts depend primarily on (1) the traffic demand in the corridor, and (2) the magnitude and duration of the capacity reductions through the construction zone. Regardless of the magnitude of the capacity reduction, the potential for corridor-wide impact does exist. Even when the actual impacts are likely to be minor, neighboring businesses and residents are likely to perceive potentially severe impacts. In either case, a corridor-wide evaluation of the likely traffic impacts and the development of a corridor traffic management plan may be necessary.

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 three components of a corridor traffic management plan are:

1. The construction zone traffic control plan,
2. Corridor-wide impact mitigation techniques, and
3. A public information program.

The traffic control plan details how traffic will be accommodated in the construction zone. Impact mitigation techniques include improvements to increase capacity and improve the level of service on alternative routes and modes of travel in the freeway corridor. The public information program provides motorists with the information they need to make wise route, mode, and departure time decisions.

This chapter identifies traffic management techniques for each component of the corridor traffic management plan. A review of previous applications of these techniques and an assessment of their cost-effectiveness was presented in Research Report 1188-1 "Synthesis of Traffic Management Techniques for Major Urban Freeway Reconstruction" (2). A methodology for evaluating which techniques may be appropriate for a particular project is presented in Chapter 3.

CONSTRUCTION ZONE TRAFFIC CONTROL PLAN

This section summarizes the basic traffic-control options available for reconstruction projects and identifies traffic management techniques that might be incorporated into the traffic control plan to facilitate traffic flow through the construction zone.

Traffic-Control Options

The construction zone traffic control plan details the allocation of available right-of-way between construction activities and traffic. In most cases, a reconstruction project requires some reduction in traffic-handling capacity. The magnitude of the capacity reduction may be divided into three basic categories:

1. Maintain the same number of lanes,
2. Long-term lane closures, and
3. Total freeway closures.

Maintain the Same Number of Lanes

At most projects, the SDHPT has been able to maintain the same number of travel lanes through the construction zone as were available before construction. Work space has been created by reducing lane widths and/or narrowing or eliminating shoulders. Generally, occasional short-term lane closures during off-peak periods are required as part of this strategy. Implementing this option requires careful construction sequencing and multiphase traffic control plans that include temporary roadways and detours within the right-of-way. Traffic impacts are minimized, but the cost and time required to complete construction are increased.

Long-Term Lane Closures

Long-term lane closures involve the closure of some, but not all, freeway lanes in one or both directions of travel during all or part of a construction phase. Traffic flow through the construction zone is possible, but on fewer lanes than existed before construction. This option provides additional work space which should reduce project duration and cost, but the traffic impacts on an urban freeway could be severe and are likely to extend throughout the entire freeway corridor.

Total Freeway Closures

A total freeway closure involves the closure of all lanes in one or both directions of the freeway. No traffic is allowed to flow through the construction zone in the affected direction(s). All motorists must use alternative routes or modes to reach their destination. This option can speed up construction, but its application is limited to freeways with adequate unused capacity on alternative routes in the corridor.

Techniques to Facilitate Traffic Flow through the Construction Zone

A number of techniques may be used to facilitate traffic flow through the construction zone (for a given traffic-control option). These include:

1. Portable concrete barriers,
2. Paddle screens,
3. Narrow lane widths,
4. Shoulder use,
5. Reversible lanes,
6. HOV-only lanes,
7. Ramp closures,
8. HOV-only ramps, and
9. Incident management techniques.

Portable Concrete Barriers

Portable concrete barriers are used at most reconstruction projects for safety reasons. They may be used to separate the work area from the travel lanes, opposing traffic flows, or HOV traffic from mixed-flow traffic. Barriers also promote smoother traffic operations, and they help maximize the available work space and the roadway capacity of a construction zone by minimizing the size of the required buffer area.

Paddle Screens

Paddle screens reduce driver distractions (i.e., rubbernecking or gawking) in the construction zone which in turn should result in lower accident frequencies and improved traffic operations. To date, several projects have utilized paddle screens with favorable results.

Narrow Lane Widths

Lane widths may be narrowed in order to provide as much work space and as many travel lanes as possible. One study of shoulder removals on urban freeways "concluded indirectly that safety is not significantly affected by narrowing lanes to 11 ft. The capacity effect of 11-ft lanes is also believed to be insignificant" (3). The 1985

Highway Capacity Manual (5) estimates that the capacity of 11-ft lanes is 3-4 percent less than 12-ft lanes. Capacity reductions for lanes narrower than 11 ft are more severe.

Shoulder Use

Narrowing or eliminating shoulders is another compromise between maximizing work space and maintaining as many travel lanes as possible in the construction zone. Therefore, shoulder use and lane width decisions must be coordinated.

Narrowing shoulder widths may allow the SDHPT to provide an additional travel lane through the construction zone. Appropriate shoulder widths are a subject of ongoing debate and research. A shoulder's width should be consistent with the function it is intended to serve and should not encourage unsafe uses. In a construction zone, the critical decision regarding shoulder width is whether or not to provide sufficient space for emergency stopping. NCHRP Report 254 (4) suggests that 8 ft is an acceptable width for emergency stopping on freeways; however, it agrees with AASHTO policy (6) that 10 ft (12 ft with high truck volumes) is preferred. Another study (3) suggested that a minimum desirable width of 2 feet should be provided between the travel lane and barrier. Shoulder widths between 2 and 8 ft should be evaluated carefully, because they may encourage parking or emergency stops which may or may not be safe.

Eliminating the shoulder (except for an appropriate buffer between the travel lane and portable concrete barrier) for use as a temporary travel lane is another option. It may be necessary to upgrade the pavement structure and widen the shoulder for it to serve this function. The benefits of shoulder usage are improved traffic operations by providing an additional travel lane and/or reduced construction time by providing more work space. If shoulders are eliminated in the construction zone, then special attention should be paid to the incident management techniques that are described later in this section.

A study of freeway shoulder removal under non-construction conditions drew several conclusions pertinent to considerations of shoulder use as temporary travel lanes during reconstruction projects (3):

- o Regarding removal of the left shoulder: "Under congested conditions (ADT/Lane greater than 20,000 vehicles per day), the removal of a left side shoulder should be considered an appropriate treatment to improve capacity and appears to improve safety as well when the project can reasonably be expected to reduce the level of congestion (ADT/Lane less than 18,000 vehicles per day)."
- o Regarding removal of the right shoulder: "It has also been concluded that left shoulder removals are preferable to right shoulder removals even though right shoulder removals are often easier to implement. Right shoulder removals appear to be safe treatments when parking opportunities exist beyond the shoulder. It would, however, appear desirable to provide paved parking areas when right shoulders are removed." (When right shoulders are removed in

construction zones, the space is generally occupied by traffic barriers and work activity area. Therefore, parking areas are not likely to be available unless intermittent shoulders or turnouts are provided.)

- o Regarding removal of both shoulders: "Adding a lane at the expense of removing both shoulders does not appear to be a practice that should be considered except in the most unusual circumstances. Sections with no shoulders appear to have higher accident rates. There is also a tendency towards higher accident severity rates on no shoulder sections. These findings are consistent with the unusually high probability of a traffic lane blockage for no shoulder sections. It has also been shown that the delay costs are likely to exceed the benefits of added capacity due to removal of all shoulders. The fact that some short sections of no shoulders have been safely implemented is the basis for suggesting that the treatment may be appropriate in limited instances; however, careful analysis is suggested."

Decisions to narrow or remove shoulders through a construction zone should be evaluated carefully. In addition to the tradeoffs between capacity and safety, consideration should be given to the effects on ramp operations, truck operations, law enforcement, and incident management.

Reversible Lanes

In most cases, the maximum available freeway capacity is needed only during peak demand periods. Therefore, another technique to optimize the capacity of a construction zone is to use reversible lanes for peak-period, peak-direction traffic flow. Typically, the number of access points to the reversible lanes will be limited; therefore, they are likely to serve primarily longer-distance travelers. 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.

HOV-Only Lanes

Another lane utilization strategy is to restrict one or more lanes to HOVs only. Any of the standard HOV-lane options (concurrent, contraflow, or barrier separated) might have application through construction zones. HOV restrictions might also be incorporated with the reversible lane technique discussed above.

Ramp Closures

Reconstruction projects often involve the realignment, relocation, and removal of ramps that necessitate their temporary or permanent closure. Ramps might also be closed as a traffic management technique. Ramp closures reduce conflicts between through traffic and merging/diverging vehicles which results in smoother traffic flow and higher capacity. Ramp closures also restrict demand on the freeway, which can eliminate bottlenecks at entrance ramps further improving traffic flow.

When evaluating ramp closures, consideration must be given to where the traffic that normally uses a ramp will go when that ramp is closed. Traffic may either divert to an upstream or downstream ramp or to an alternative route/mode in the corridor. Therefore, the corridor-wide impacts of ramp closures should be considered when evaluating this technique.

The appropriateness and effectiveness of ramp closures is site-specific and depends upon such factors as:

1. Normal freeway and ramp volumes,
2. Ramp locations,
3. Freeway and ramp geometries,
4. Origin-destination patterns of ramp users, and
5. Operating conditions on the frontage roads and arterial streets in the corridor.

HOV-Only Ramps

A variation of the ramp-closure technique is to restrict one or more ramps to HOVs only. The effect of HOV-only restrictions at entrance ramps is similar to that of ramp closures (i.e., they reduce traffic demands on the freeway and reduce vehicle merging conflicts which can improve traffic flow and increase roadway capacity). HOV-only restrictions coupled with ramp closures may also produce the travel time savings that are necessary to attract additional ridesharing and bus ridership.

Incident Management Techniques

Incident management techniques may be used to reduce incident detection and response times during construction. Whereas quickly detecting and responding to freeway incidents is important under normal conditions, it often becomes even more vital during construction when shoulders are narrowed or converted to travel lanes, ramps are closed within the construction zone, and portable concrete barriers (used to separate traffic from the work area) limit access by emergency and service vehicles.

Techniques that should be considered during construction projects include:

1. Increasing police patrols,
2. Initiating or expanding a motorist assistance program (i.e., service patrols),
3. Installing emergency telephones for motorists,
4. Utilizing existing or providing interim freeway surveillance systems,
5. Providing free tow-truck service, and
6. Providing accident investigation sites.

Police and service patrols, emergency telephones, and surveillance systems help reduce incident detection time. Free tow-truck service facilitates incident response. Accident investigation sites facilitate incident removal and reduce the duration of lane blockages. Emergency telephone locations should be selected carefully to insure motorists can safely park, walk to, and use the telephones. Accident investigation sites are likely to be good locations for emergency telephones.

Summary

Traffic-control options for freeway reconstruction projects may be grouped into three categories: (1) maintain the same number of lanes, (2) long-term lane closures, and (3) total freeway closures. Experiences from previous projects suggest that each option can work effectively when implemented as part of a corridor traffic management plan.

A number of techniques are available to facilitate traffic flow through the construction zone. The use of portable concrete barriers is common, and the use of paddle screens merits consideration. Narrowing lane widths and narrowing or eliminating shoulders may be a necessary compromise in order to maintain as many travel lanes as possible. Reversible or HOV-only lanes may not have widespread application, but where appropriate they can improve traffic flow and increase people-handling capacity. Ramp closures or HOV restrictions can improve traffic flow through the construction zone by reducing traffic demands and eliminating merging/diverging conflicts; in evaluating these techniques the corridor-wide impacts must be considered. Serious consideration should be given to expanding incident management capabilities during reconstruction projects, especially when shoulders are removed.

CORRIDOR-WIDE IMPACT MITIGATION TECHNIQUES

Impact mitigation techniques are improvements to alternative routes and modes in the corridor that help accommodate the traffic that diverts from the construction zone. A wide range of transportation systems management (TSM) and traffic engineering

techniques might be employed to: (1) increase the capacity and improve operating conditions on alternative routes in the corridor, or (2) improve service and increase ridership on public transit and ridesharing alternatives.

Improvements to Alternative Routes

Experiences from past projects where capacity reductions were required on the freeway indicate that the most common diversion response by drivers was to change routes. Consequently, the actions implemented on alternative arterial routes can be extremely important to maintaining adequate traffic movement through the corridor. Techniques to increase the capacity and improve operations on alternative routes can be grouped into the following categories:

1. Traffic signal improvements,
2. Other intersection improvements, and
3. Other roadway improvements.

Traffic Signal Improvements

Signalized intersections are the primary restrictions to the flow of traffic along most arterial streets. Signalized intersections limit the overall traffic-carrying capacity of the alternative routes in the corridor and, thereby, the amount of diverted traffic that can be accommodated during a freeway reconstruction project. Consequently, actions to accommodate additional traffic at signalized intersections are vital to the successful management of traffic during freeway reconstruction.

Two basic types of signal improvements at intersections on alternative routes are:

1. Adjustments in signal phasing, timing, and coordination, and
2. Improvements in signal equipment.

Adjustments in Signal Phasing, Timing, and Coordination. Signal operations which are optimal for existing traffic patterns are likely not to be optimal if traffic patterns change during the reconstruction project. Adjustments in signal phasing, timing, and coordination may be required to accommodate anticipated changes in traffic patterns and/or to encourage diverted traffic to use selected routes. Under normal conditions, signals are generally timed to provide approximately equal levels of service on all approaches. During reconstruction, it may be necessary or desirable to give preferential treatment to those approaches that will serve diverted traffic.

Improvements in Signal Equipment. In order to provide the efficiency of signal operations that may be required during reconstruction, it may be necessary to upgrade

existing signal control equipment. Potential improvements in signal equipment include the installation of temporary traffic signals, traffic-actuated signals, time-based coordination, and computerized traffic control systems.

Signal timing changes are relatively inexpensive, yet they can result in significantly improved traffic operations at the intersections and along the entire arterial. The effect of the improvements will depend upon changes in traffic volumes and turning percentages, roadway geometries, 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. It must also be remembered that improvements in traffic signal hardware will continue to provide benefits to the public even after the reconstruction project is completed.

Other Intersection Improvements

Typically, the amount of diverted traffic that an arterial street can accommodate is significantly restricted by only a few intersections. Therefore, it may be possible to achieve large increases in the capacity of an arterial by making spot improvements at selected intersections. Such intersection improvements include:

1. Left-turn prohibitions,
2. Additional lanes, and
3. Police officer control.

Left-Turn Prohibitions. The prohibition of left-turns at all or only selected intersections along an arterial can significantly increase the amount of diverted traffic that can be accommodated. At intersections with left-turn bays, left-turn prohibitions may enable an exclusive left-turn phase to be eliminated with the green time reallocated to the through movement. At intersections without turn bays, left-turn prohibitions eliminate the impedance to through traffic by queued left-turning vehicles. Prohibitions may or may not be restricted to peak periods.

Additional Lanes. At some intersections (particularly those with major cross streets), adding lanes may be the only way to provide significant increases in the amount of diverted traffic that can be accommodated. Potential techniques for adding lanes include restriping, channelization, or minor widening. Critical movement analysis will determine the movements for which additional lanes would be the most beneficial.

Police Officer Control. Police officer control should typically be considered only as a temporary or interim technique for improving traffic flow through an intersection. It has been used and may be appropriate during the first few days or weeks of a project, until motorists adjust and settle into new traffic patterns and more permanent changes in signal operations or intersection geometries can be provided to accommodate diverted traffic. Police officer control may also be needed to insure safe operations at intersections with

significant pedestrian volumes, particularly school crossings. (If possible, of course, diverted traffic would generally be discouraged from using alternative routes with major school crossings.)

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 geometries, turning movements, and intersection operating conditions before the improvements. In general terms, turning prohibitions and restriping are the least costly to implement, requiring mainly signal, signing, and marking changes and some enforcement. Channelization and widening to add lanes are more capital-intensive, but will continue to provide benefits after the reconstruction project is completed. Police control is labor-intensive and costly to implement but may be beneficial at the beginning of projects when it is difficult to predict the impacts of construction upon alternative routes in the corridor.

Other Roadway Improvements

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

1. Reversible lanes,
2. One-way street pairs,
3. Pavement marking changes,
4. Parking prohibitions,
5. Signing and lighting improvements,
6. Pavement improvements, and
7. Accelerated maintenance.

Reversible Lanes. On arterials where traffic flow is imbalanced by direction, it may be possible to designate reversible lanes to better accommodate peak-period, peak-direction travel without seriously affecting off-peak direction traffic. Implementing reversible lanes typically requires changes in striping, signing, and signal operations. The reversible lanes may serve mixed-flow traffic or be restricted to HOVs only. Caution must be exercised in the planning, design, and implementation of new reversible lanes to insure that the use of the lane is clear, consistent, and unambiguous for all traffic movements.

One-Way Street Pairs. The advantages and disadvantages of converting two-way streets to one-way pairs are widely recognized. The ability to accommodate additional diverted traffic due to the capacity advantages of one-way pairs may provide a compelling reason for conversions during a reconstruction project.

Pavement Marking Changes. On some routes, it may be possible to add lanes by restriping narrower lanes. NCHRP Report 330 (Z) evaluated "the effective use of narrower lanes as part of traffic operational improvement strategies for urban arterial streets" and concluded that "... in many situations traffic operational benefits, traffic safety benefits, or both can be obtained from the use of narrower lanes." It evaluated the use of narrower lanes to add travel lanes or a median treatment (raised or two-way left-turn lane). It advocated that "where streets cannot be widened, highway agencies should give strong consideration to the use of 10-ft lanes where they are necessary as part of a geometric improvement to improve traffic operations or to alleviate specific accident patterns," but cautioned that "lane widths less than 10 ft should be used cautiously and only in situations where it can be demonstrated that increases in accident rates are unlikely."

Parking Prohibitions. The prohibition of on-street parking, in conjunction with appropriate pavement marking changes, is another technique that might be used to add lanes along an arterial street. In evaluating this technique, consideration must be given to the availability of off-street parking alternatives.

Signing and Lighting Improvements. Additional signing may be required to designate streets as detour routes and/or to direct diverted traffic to and from the freeway. Lighting improvements may be necessary to improve security and safety along alternative routes.

Pavement Improvements. The existing pavement on some routes may not be structurally adequate or in sufficiently good condition to accommodate diverted traffic. Therefore, pavement improvements may be necessary to improve safety and facilitate traffic flow.

Accelerated Maintenance. Maintenance and utility work and any other activities that might reduce the capacity of alternative routes should be avoided during a major freeway reconstruction project. A concerted effort should be directed toward anticipating such activities and accelerating (or delaying) their schedule so as to avoid the reconstruction period. Cities that issue permits for lane closures might tighten their regulations in coordination with reconstruction project activities.

Summary

Experiences at past reconstruction projects have shown that selected improvements along alternative routes in the corridor can enable those routes to accommodate considerable increases in traffic without causing intolerable 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 diversion to the alternative routes has occurred. If the same number of lanes is maintained, and there are only minor capacity reductions due to narrow lanes or shoulders and short-term off-peak lane closures, then less diversion to alternative routes is likely and improvements along those routes may be less critical.

The costs of improvements on alternative routes vary widely. Some improvements, such as signal timing changes, are relatively inexpensive. Other improvements, such as intersection channelization and widening or changes in signal equipment, are more capital-intensive. From a practical standpoint, the less expensive techniques are easiest to justify and 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 reconstruction project. However, since these improvements remain in place after the project is completed, the cost-effectiveness evaluation should include the post-construction benefits. It may be possible to accelerate the implementation of improvements already planned for alternative routes so that they are in place before construction begins.

Techniques to Increase Public Transit Ridership and Ridesharing

Encouraging motorists to shift trips to public transit or to other HOV modes is one strategy for reducing demand through the construction zone and mitigating the impacts of diverted traffic elsewhere in the corridor. Furthermore, a reconstruction project may provide the additional incentive some motorists may need to change their mode of commuting and may be seen as an opportunity to produce desired increases in transit ridership and ridesharing. Many techniques are available to promote public transit and ridesharing as travel alternatives, including:

1. New or expanded bus service,
2. Preferential treatment for buses and HOVs,
3. New and expanded commuter park-and-ride lots,
4. New or expanded ridesharing programs, and
5. New or expanded rail service.

New or Expanded Bus Service

Improvements in bus service during construction projects may include the following actions:

1. New, expanded, or revised routes,
2. Additional buses in service, and
3. Improved passenger services.

New, Expanded, or Revised Routes. In order to accommodate changes in traffic conditions and increases in demand, it may be necessary to add bus routes to better serve the affected corridor, expand routes to extend their coverage area, or revise routes to reduce travel time or increase service reliability. Improvements may be made to express and/or local service. Street improvements may be required to accommodate buses on new routes (8, 9).

Additional Buses in Service. Additional buses may be required on existing routes in order to decrease service headways. If traffic conditions on routes deteriorate sufficiently, then additional buses may be required simply to maintain existing headways. It may also be necessary to have additional back-up buses on call to respond to unexpected delays or breakdowns.

Improved Passenger Services. Improved passenger services, including bus stop shelters and route information services, should be coordinated with the other actions. New bus stops may be required along new or expanded routes. Special marketing and public information programs may be required to serve the needs of new riders.

Preferential Treatment for Buses and HOVs

Several forms of preferential treatment for buses and HOVs have already been discussed, including HOV-only restrictions at ramps and HOV lanes through the construction zone or on alternative routes in the corridor. HOV-only ramps or lanes can improve traffic flow and increase people-handling capacity in the construction zone and throughout the corridor. Other forms of preferential treatment include priority traffic signals, parking spaces, and parking rates (10). These techniques can help produce travel time savings that are necessary to promote HOV utilization and reduce travel demand during construction.

Improvements in Commuter Park-and-Ride Lots

The initiation and expansion of park-and-ride lots for bus transit and other HOV users are often necessary if increased HOV usage is to be realized. Methods of obtaining the land for the lots include:

1. Use of land already owned by the highway agency,
2. The purchase of land,
3. Leasing the land on a short-term or long-term basis, and
4. Agreements to use private (shopping center, church, etc.) parking lots.

The costs of a park-and-ride lot depend on how it is obtained as well as on the improvements made and/or the amount of security provided. A key to the successful implementation of park-and-ride lots during construction is the flexibility to add or delete capacity and to discontinue those lots that are not used. Consequently, leasing land or obtaining permission to use existing parking lots would be quite appropriate and provide the flexibility needed to update and modify those services.

New or Expanded Ridesharing Programs

An important action at many freeway reconstruction projects may be the introduction or expansion of ridesharing programs (both vanpools and carpools). Actions may include expanded commuter matching programs and public information campaigns to promote the service. 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 can influence ridership.

New or Expanded Rail Service

Commuter rail service is not presently available in Texas urban areas, but it is being planned in Dallas and Houston. The rail service to be implemented in the North Central Expressway corridor in Dallas could be a travel alternative during the latter stages of the reconstruction of the North Central Expressway. The same could be true in other corridors in the future.

Summary

A wide range of techniques may be used in an attempt to divert vehicle-trips from the freeway construction zone to public transit and other HOV modes. At past projects, expansions of existing transit systems have been more successful than initiating new systems. Since it is difficult to 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.

Experiences to date suggest that a reconstruction project by itself is unlikely to cause large numbers of motorists to change long-held travel habits regarding their choice of travel mode. At some past projects, moderate increases in usage were achieved, but at other projects changes were negligible. Travel time savings for bus transit and HOVs are a key to increases in ridership. However, a major reconstruction project could be an ideal time to implement transit and HOV 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 to change modes.

PUBLIC INFORMATION PROGRAM

Public information programs have become an essential component of corridor traffic management plans for freeway reconstruction projects. These programs 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. Available techniques are described in the following paragraphs.

A variety of public information techniques may be used to disseminate information to the public. The appropriate tools depend on both the intended audience and the type and amount of information to be provided. Techniques may be grouped into the following categories:

1. Traditional public information tools,
2. Special publications,
3. Toll-free hotlines,
4. Changeable message signs,
5. Other special signing,
6. Highway advisory radio,
7. Ombudsman, and
8. Emerging technologies.

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 tools are in addition to the media coverage that typically accompanies a major reconstruction 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 may include the following:

1. Posters,
2. Pamphlets,
3. Newsletters,
4. Maps, and
5. Special mailings.

Experience to date indicates that these techniques can be 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. These publications may be distributed at the project or public information office, public meetings, public displays at shopping malls or major employers, and presentations to special groups. They may also be mailed separately or as inserts in utility or telephone bills.

Toll-Free Hotlines

Toll-free hotlines provide a way for the public to obtain up-to-date information concerning traffic conditions and construction schedules as well as to voice their concerns and complaints about a project. A hotline may be operated manually or using recorded messages.

Changeable Message Signs

Changeable message signs can be effective at keeping motorists informed about lane closures and changes in traffic control during the project. When using changeable message signs, it is important that available guidelines on their design and application be followed (11).

Other Special Signing

Special informational signing is a commonly used technique. This category includes: (1) special signing designating alternative routes or warning of changes to a traffic control plan such as ramp closures, and (2) large billboard advertisements to encourage ridesharing during construction.

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. The ability of highway advisory radio to influence driver travel patterns has been well documented, and guidelines regarding the operation of highway advisory radio are available (11).

Ombudsman

An ombudsman is a government official who investigates citizens' complaints against a governmental agency. During one reconstruction project, an ombudsman was designated to work with community organizations as well as individuals to resolve home or business problems related to dust, noise, cracked walls or other impacts caused (or perceived to be caused) by the construction.

Emerging Technologies

A variety of other emerging technologies are being developed that could be used effectively during reconstruction projects either now or in the foreseeable future. For example, two experimental systems being tested in the Houston area are: (1) the use of cellular telephone to transmit real-time information to and from a central control center, and (2) the installation of video monitors in the Greenway Plaza complex to provide information on traffic conditions during the US-59 Southwest Freeway reconstruction project. As these and other technologies become available, their application to reconstruction project public information programs should be evaluated.

3. CORRIDOR ANALYSIS METHODOLOGY

This chapter presents a corridor analysis methodology for urban freeway reconstruction projects. The methodology is based upon a review of the planning procedures followed at a number of projects in Texas and elsewhere throughout the United States (1, 2, 12). It is a compilation of the steps that are typically followed in developing the corridor traffic management plan for a project.

The objectives of the methodology are to:

1. Identify the type and magnitude of potential traffic management problems expected during typical urban freeway reconstruction efforts.
2. Identify alternative impact mitigation techniques that could be implemented during freeway reconstruction.
3. Assess the cost and potential effectiveness of these techniques.
4. Select appropriate impact mitigation techniques for use during freeway reconstruction.

First, an overview of the methodology is presented. Then, each step is discussed in more detail. The guidelines for each step identify the analyses that must be performed and the tools that are available to aid in the analyses.

In addition, italicized examples are presented to illustrate the application of the methodology. The examples are drawn from a demonstration study of the US-59 Southwest Freeway reconstruction project in Houston. The demonstration study was conducted to test and refine the methodology based upon experience with its use on an actual project.

OVERVIEW OF THE METHODOLOGY

Figure 1 is a flowchart of the methodology. The first two steps are to inventory the affected corridor and identify the traffic-control options to be evaluated. These steps are interrelated. Knowledge of conditions in the corridor (particularly current traffic volumes and the availability of unused capacity on alternative routes) influences the selection of traffic-control options. Conversely, the traffic-control options that are being considered influence the scope of the inventory. For example, if significant reductions in capacity are being considered, then all routes that are likely to be affected should be inventoried. On the other hand, if only limited excess capacity is available in the corridor, then it may be imperative to minimize the capacity reductions on the freeway.

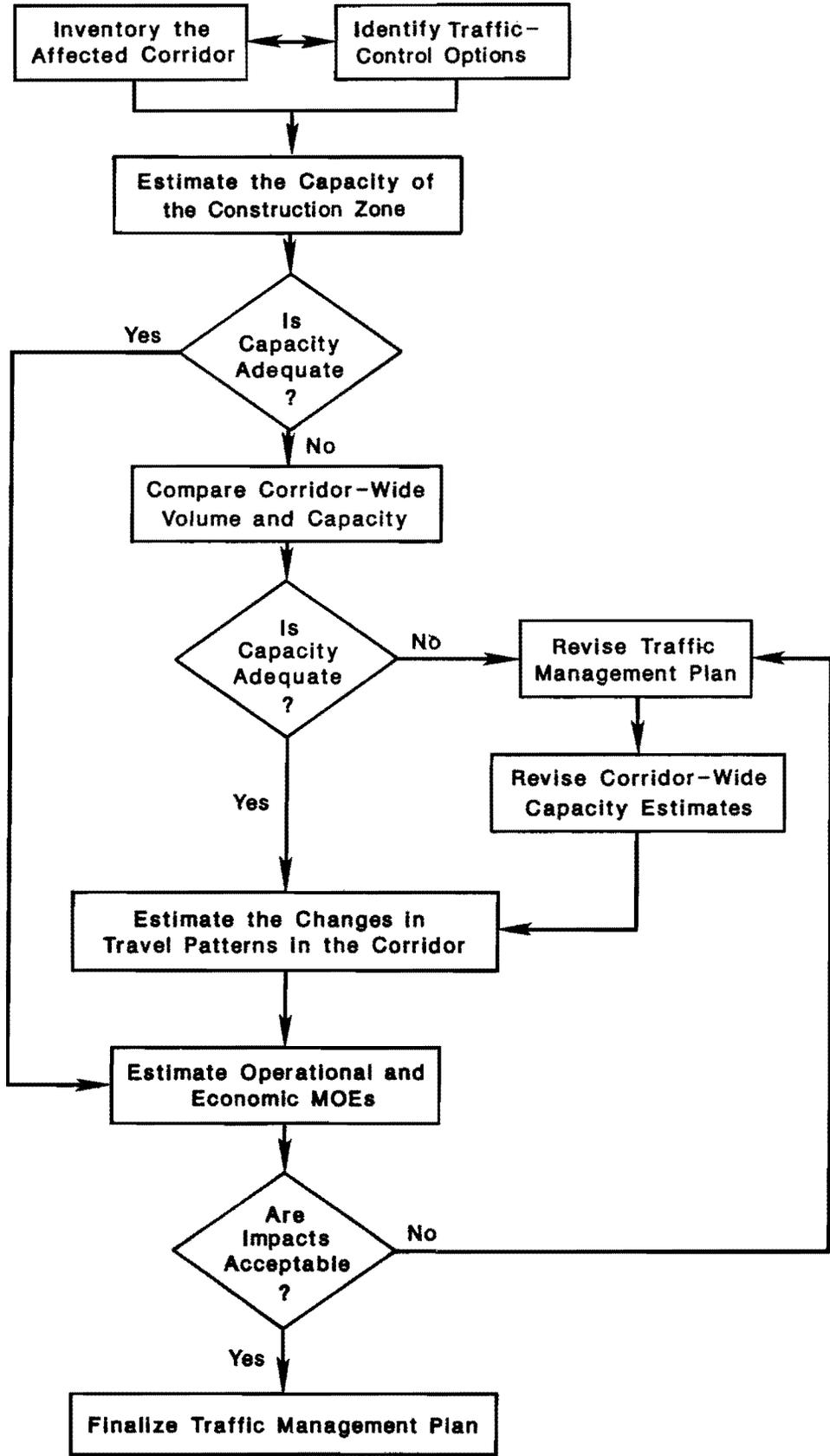


Figure 1. Flowchart of the Corridor Analysis Methodology

A major determinant of the severity of the travel impacts is the magnitude of the reduction in freeway capacity. Therefore, the first step in evaluating a particular traffic-control option is to estimate the capacity of the construction zone.

If the capacity of the construction zone is adequate to accommodate normal traffic volumes (i.e., what the traffic volumes would be without the reconstruction project) at an acceptable level of service, then the scope of the evaluation may be restricted to the freeway and frontage roads. In this case, the analysis methodology is straightforward and may proceed directly to the estimation of operational and economic measures of effectiveness (MOEs) for comparison with other options.

If the capacity of the construction zone is not adequate, then some traffic would be forced to divert to alternative routes and modes in the corridor. The travel impacts would extend beyond the freeway and, therefore, the scope of the evaluation should be corridor-wide. On most heavily-traveled urban freeways, even minor capacity reductions can have impacts throughout the corridor, and a corridor analysis would be appropriate.

The remainder of the flowchart represents the steps required to perform a corridor analysis. The objectives of the corridor analysis are to: (1) determine the need for impact mitigation techniques, (2) identify and evaluate alternative techniques, and (3) select those that can effectively supplement a given traffic-control option in a corridor traffic management plan. A corridor analysis has two dimensions: (1) an analysis of all routes across the width of the corridor, and (2) an analysis of individual alternative routes along the length of the corridor.

For a project that requires a corridor analysis, the next step would be to compare corridor-wide traffic demands and capacities. A screen line analysis procedure (i.e., an analysis of all routes across the width of the corridor) that computes a corridor volume-to-capacity (v/c) ratio is used to make this comparison.

If the total capacity of all routes and modes in the corridor appears sufficient to accommodate normal corridor-wide traffic volumes at an acceptable level of service, then the evaluation may proceed to the estimation of the changes in travel patterns in the corridor. However, if the existing capacity in the corridor is inadequate, then it may be necessary to revise the traffic management plan.

Revising the traffic management plan involves identifying, evaluating, and selecting impact mitigation techniques to supplement the traffic-control option. Any of the techniques described in Chapter 2 may be considered. An analysis of individual alternative routes along the length of the corridor is required to evaluate the cost-effectiveness of techniques.

The corridor-wide capacity estimates should be revised to reflect the impact mitigation techniques that are selected for the corridor traffic management plan. The screen line v/c ratios should be revised to reflect the capacity increases.

Estimates of the changes in travel patterns in the corridor are needed to determine the traffic movements that could be served by each alternative route and to identify and evaluate the impact mitigation techniques that could facilitate those movements and, thereby, increase the amount of diverted traffic a route could accommodate.

Operational and economic MOEs are needed to evaluate the effectiveness of the various elements of the corridor traffic management plan. Operational MOEs, including travel times and average speeds, and economic MOEs, particularly road user costs, are needed to compare the costs and benefits of the impact mitigation techniques.

If the travel impacts on individual routes in the corridor are unacceptable, then the corridor traffic management plan should be revised to incorporate additional impact mitigation techniques or the traffic-control option should be eliminated from further consideration. If the plan is revised, it should be re-evaluated. The methodology continues until the traffic management plan is finalized.

STEPS IN THE METHODOLOGY

Inventory the Affected Corridor

The purpose of the inventory is to collect all data that will be required to identify potential problems and evaluate alternative traffic management techniques. Some of the data is likely to be available within the SDHPT or from local government agencies and will simply need to be compiled and organized. Other data will need to be collected in the field.

The inventory can be broken into four parts:

1. Define the boundaries of the affected corridor,
2. Inventory the transportation facilities and services in the corridor,
3. Inventory the current usage in the corridor, and
4. Estimate operational MOEs for existing conditions.

Define the Boundaries of the Affected Corridor

The affected corridor includes the freeway being reconstructed as well as the alternative routes and modes of travel that are likely to be impacted by the project. The extent of the region affected by a reconstruction project depends primarily upon:

1. The existing traffic volumes on the freeway being reconstructed,

2. The severity of the capacity reductions through the construction zone,
3. The availability of unused capacity on alternative routes,
4. The availability of alternative modes of travel including HOV and bus and rail transit facilities and services, and
5. The opportunities to increase the capacity of alternative routes and modes.

The scope of the evaluation should include all routes on which: (1) unused capacity is currently available, (2) additional capacity could be developed that would be used by diverted traffic, or (3) significant changes in travel patterns are expected during reconstruction. Individuals with good knowledge of local conditions should be able to identify alternative routes that might be selected by motorists normally using the section of freeway being reconstructed. Consideration should also be given to routes that might be affected by secondary diversion (i.e., when motorists divert from the freeway to a parallel arterial close to the freeway, motorists on that arterial may divert to another arterial further from the freeway).

For the US-59 Southwest Freeway project in Houston, the corridor illustrated in Figure 2 was identified. It was concluded, based upon discussions with various state and local officials, that alternative routes as far north as Westheimer and as far south as Bellfort could be affected. That is, these routes could serve certain trips normally served by the freeway. Most attention, however, was focused on the freeway, frontage roads, and the four arterial streets closest to the freeway (Richmond, Westpark, Bellaire, and Bissonnet). The limits of construction, which extended from Beltway 8 to Shepherd/Greenbriar, defined the western and eastern boundaries of the corridor.

Inventory the Transportation Facilities and Services in the Corridor

The transportation facilities and services that should be inventoried include:

1. The freeway (and frontage roads) being reconstructed,
2. The major parallel arterial streets to which freeway traffic might divert,
3. Other surface streets that may also be impacted (e.g., cross streets and parallel arterial streets that might experience secondary diversion),
4. Existing bus and rail transit routes and terminals, and
5. HOV services and facilities including carpool/vanpool programs and park-and-ride lots.

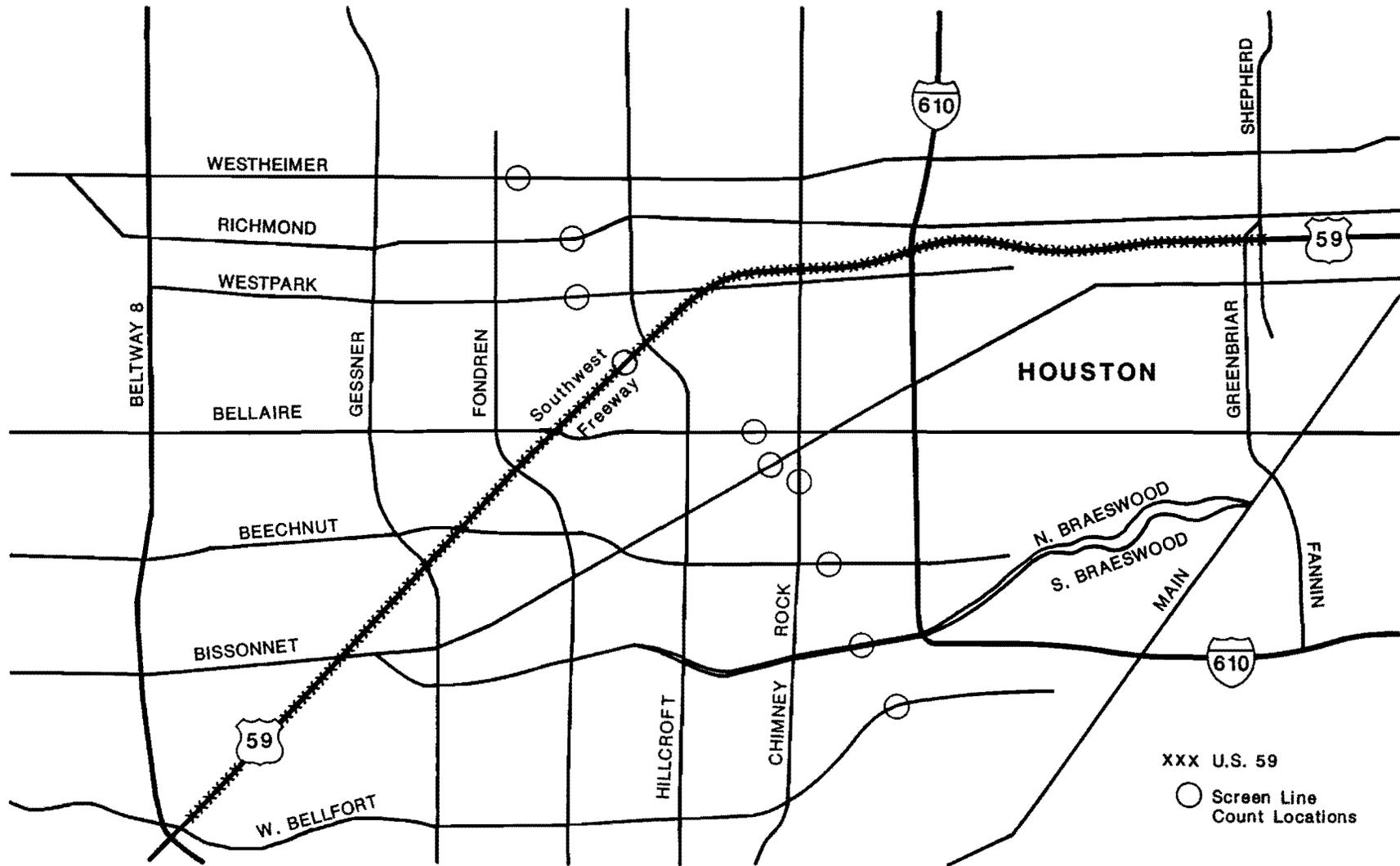


Figure 2. Map of the US-59 Southwest Freeway Corridor in Houston

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

1. The roadway cross section (number of travel lanes, lane and shoulder widths, median type, and on-street parking);
2. Restrictions on turning movements or use by trucks (and whether the restrictions are for operational, geometric, or structural reasons); and
3. Traffic signals and other controls (location of signal- or stop-controlled intersections; type of control; and signal phasing, timing, and coordination).

This information is necessary to estimate the impact of reconstruction on freeway traffic conditions, the availability of unused capacity on alternative routes and modes, and the opportunities to increase capacity in the corridor. Project personnel are likely to already know much of this information. Site visits may be necessary to collect or verify roadway data. Data on alternative modes should be available from the regional transit authority or local transportation agency, and traffic signal control information should be available in the files of the local transportation department.

For the US-59 Southwest Freeway project in Houston, the highway facilities inventory data were obtained during drive-throughs of the various routes in the corridor. The signal-controlled intersections were identified in the field, and signal timing data for those locations were obtained from the files of the City of Houston Transportation Department. Schematics of the geometrics of the intersections were sketched in the field. Data on bus transit and HOV facilities and services were available from the Harris County Metropolitan Transit Authority (METRO).

Inventory the Current Usage in the Corridor

The volume and character of traffic using the freeway and the alternative routes should be determined. The ridership on the existing bus and/or rail transit routes in the corridor should also be obtained.

Important usage data on the highway network may include:

1. Directional traffic volumes (daily and hourly),
2. Intersection turning movement counts,
3. Vehicle classification,
4. Auto occupancy, and
5. The origins and destinations of current users of the section of freeway being reconstructed.

Directional volume counts across one or more screen lines may be used to assess the availability of sufficient capacity in the corridor to accommodate freeway capacity reductions through the construction zone. Counts should be taken on the freeway, frontage roads, and arterials streets where those routes cross the screen line. Since volumes and capacities may vary through the length of the corridor, it may be necessary to study several screen lines. Screen lines will typically be located along major arterials that run perpendicular to the freeway, since they are likely to restrict the volume of traffic that can travel through the corridor. A screen line should also pass through the freeway link whose capacity will be most restricted during reconstruction.

Intersection turning movement counts are needed to perform more detailed analyses of the ability of individual arterials to accommodate traffic diverted from the construction zone. Vehicle classification data are needed to determine whether special provisions are required to accommodate truck traffic. Auto occupancy data would be used primarily for monitoring shifts in mode and the total number of person-trips served in the corridor. Some of the count data may be available in the files of the SDHPT or local agencies, but some data collection is likely to be required to fill gaps. Standard procedures may be used to perform the required data collection (13).

Origin-destination (O-D) data are useful in identifying attractive alternative routes. O-D data are generally more expensive to collect than other usage data. Major traffic generators in the corridor should be identified. The O-D patterns of affected freeway users may be estimated from regional travel models using select link analysis. At projects for which long-term lane closures are being considered, the cost of a ramp O-D study may be justified in order to better identify and evaluate needed improvements on alternative routes and modes. On the other hand, individuals with good knowledge of local travel patterns may have sufficient information to make appropriate evaluations.

For the US-59 Southwest Freeway project, the screen line illustrated in Figure 2 was selected. The screen line ran approximately perpendicular to the Freeway and was located just west of the major inbound bottleneck (between Westpark and I-610). Continuous 15-minute, directional volume counts were obtained for the mid-week period (Tuesday through Thursday) at all major routes intersecting the screen line. This screen line was selected to capture any changes in traffic patterns that might result from the reconstruction project. Since the Southwest Freeway runs diagonally through the arterial network grid, the screen line does not run along an individual cross street as might normally be the case. Another screen line location that might have been selected would be along I-610. Short-duration (30-60 minute) vehicle classification counts were conducted during a.m., off, and p.m. peak periods on the freeway and selected arterial streets. Intersection turning movement count data were obtained from the City of Houston Transportation Department for all intersections on the four primary alternative routes (Richmond, Westpark, Bellaire, and Bissonnet). Major traffic generators (large employers, shopping malls, office complexes, etc.) were identified.

Another example that might be more typical is the screen line pattern selected for evaluating the North Central Expressway reconstruction project in Dallas. As illustrated in Figure 3, the North Central Expressway corridor between I-635 and the Dallas central business district has a number of arterial streets that run parallel to the Expressway and several major arterials that run perpendicular to the Expressway. Three of these major cross streets (Northwest Highway, Mockingbird Lane, and Oak Lawn/Lemmon/Peak) were selected as screen line locations. The three screen lines represent critical locations for different segments of construction. In addition, the Expressway itself was selected as a fourth screen line to monitor east-west traffic, since the reconstruction project will include work on cross street overpasses and underpasses.

Estimate Operational MOEs for Existing Conditions

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

For the US-59 Southwest Freeway project, travel time runs were performed in the peak direction at ½-hour intervals on the Southwest Freeway and at 1½-hour intervals on the frontage roads and 4 arterial streets from 6-11 a.m. and 2-7 p.m. during the mid-week. In addition to the total travel time, intermediate travel times were recorded at each signalized intersection on the arterial routes. A vehicle-installed distance-measuring instrument was used to record distances so that average speeds could be computed. Figure 4 is an example of a speed profile for Westpark, on which potential bottleneck locations were identified as the links with the lowest average speeds. The links approaching Gessner, Hillcroft, Chimney Rock, and S. Rice appear to be the principal bottlenecks on Westpark.

Identify Traffic-Control Options

The corridor analysis methodology illustrated in Figure 1 is structured to evaluate one traffic-control option at a time. Therefore, if several options are to be evaluated, the methodology would be repeated for each.

Three basic traffic-control options were identified in Chapter 2:

1. Maintain the same number of lanes,
2. Long-term lane closures, and
3. Total freeway closures.

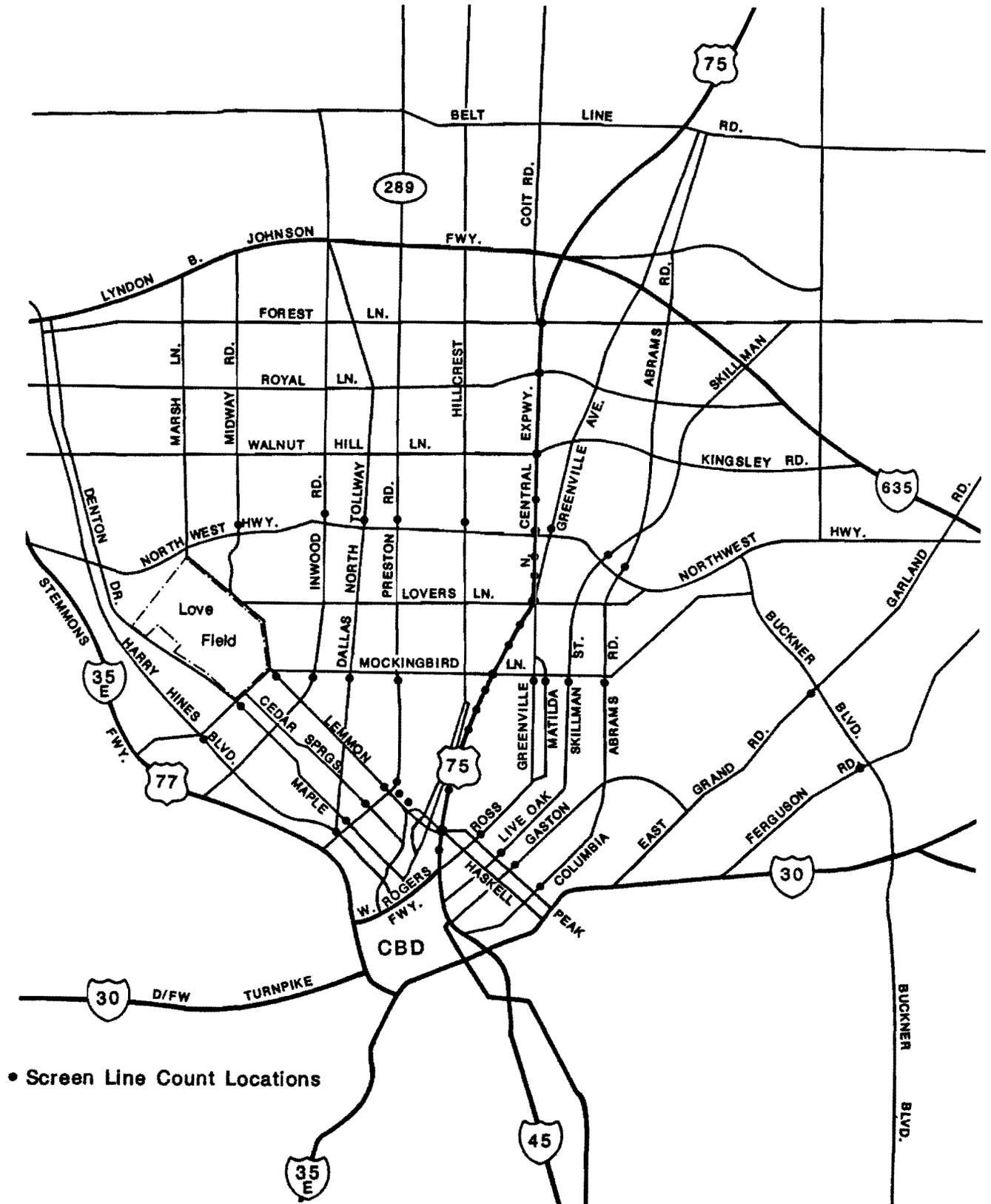


Figure 3. Map of the US-75 North Central Expressway Corridor in Dallas

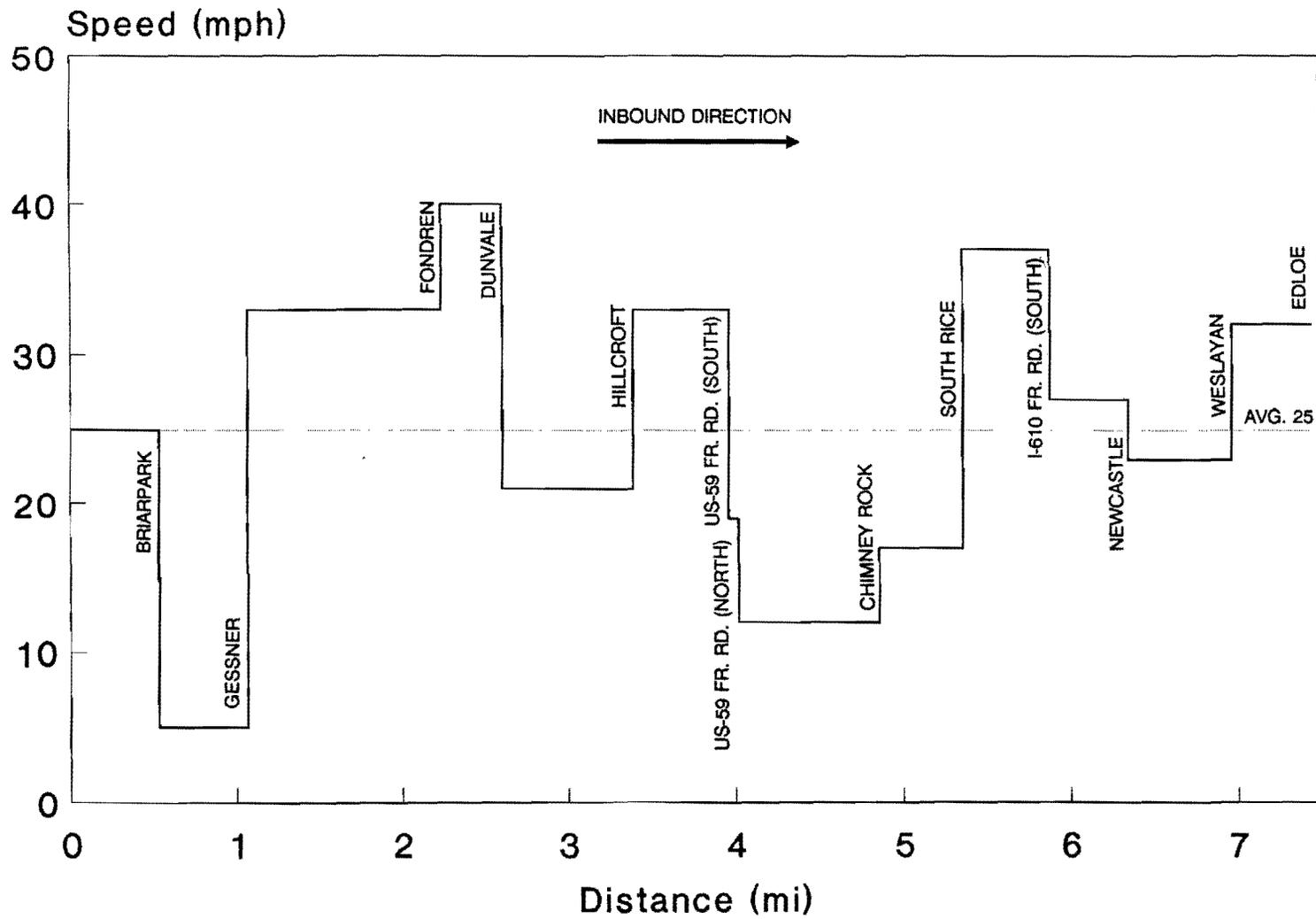


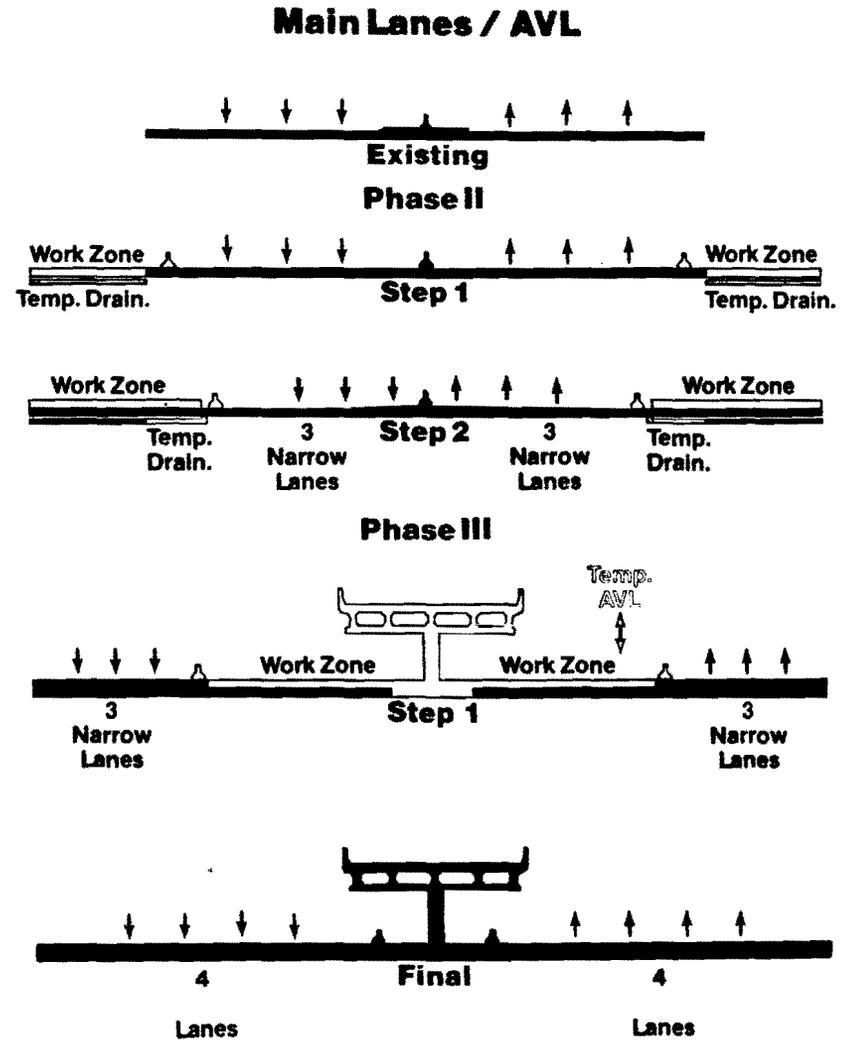
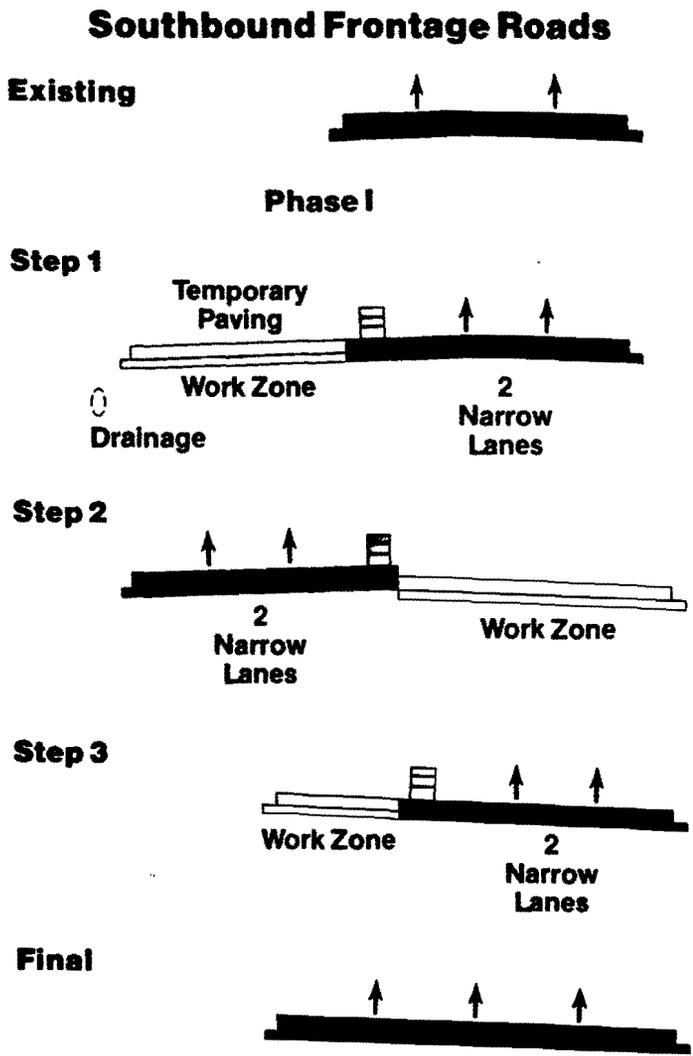
Figure 4. A.M. Peak-Hour, Peak-Direction Speed Profile for Westpark

From the point of view of developing a corridor traffic management plan, many factors must be considered when selecting a traffic-control option for the construction zone. 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,
5. The availability of excess capacity or the ability to increase capacity on alternative routes and modes in the corridor,
6. The volume of traffic that might divert to these alternative routes and modes, and
7. The goals and policies of the Department with respect to acceptable levels of travel impacts.

The existing cross section of the freeway and the available right-of-way define the supply of space that must be divided between the needs of both the construction 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 a function of the volume of traffic that must be accommodated on the freeway during reconstruction. 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 to the routes), then lane closures or total freeway closures can be considered as possible traffic-control options.

The typical cross section of US-59 before construction was three mainlanes in each direction west of I-610 and four mainlanes in each direction east of I-610. The three-lane, one-way frontage roads were discontinuous between Hilcroft and I-610. Two traffic-control options were evaluated during the demonstration study of US-59 Southwest Freeway project: (1) maintaining the same number of lanes as before reconstruction, but with minor capacity reductions due to the narrowing of lanes and shoulders, and (2) closing one lane in each direction. In reality, the first option had already been selected and implemented. The long-term lane closure option was evaluated only to demonstrate the methodology. The typical construction sequencing that was actually developed is illustrated in Figure 5. Phase I involves frontage road and intersection improvements, during which time two narrow lanes are maintained on the frontage roads, and the mainlanes are essentially unaffected. As part of Phase I, the frontage road is extended to Westpark. Mainlane and transitway construction are conducted during Phases II and III, during which the typical cross section consists of three narrow lanes (11 ft) with varying shoulder widths (from as much as 7 ft to as little as 1-2 ft).



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Figure 5. Typical Construction Sequencing for the US-59 Southwest Freeway Reconstruction Project in Houston

Estimate the Capacity of the Construction Zone

The first thing that must be done in evaluating a traffic-control option is to determine the changes in capacity through the construction zone. The capacity of the construction zone is a major determinant of the magnitude of travel impacts. Capacities should be estimated for each freeway and frontage road link through which a screen line passes and for other potential bottleneck locations. Consideration must be given to the dynamics of freeway traffic flow and the effects of changes in ramp locations and volumes in order to identify potential bottleneck locations during construction and to estimate their capacity.

Unfortunately, available data on the capacity of construction zones is limited. Table 4 summarizes the data presented in Chapter 6 of the 1985 Highway Capacity Manual (5). These data apply to construction zones with portable concrete barriers and long-term lane closures. For other traffic-control options, the best available tool for estimating capacity is the standard freeway capacity analysis procedures in Chapters 3-5 of the Highway Capacity Manual (5). These procedures can be used to estimate capacity based upon the geometry of the construction zone and the traffic composition data obtained during the inventory of the corridor. It may be necessary to adjust the standard capacity estimates to account for the capacity-reducing effect of reconstruction activities adjacent to the travel lanes. However, the Highway Capacity Manual may be sufficiently conservative that the standard capacity estimates could be used directly.

TABLE 1. CAPACITY OF LONG-TERM CONSTRUCTION SITES WITH PORTABLE CONCRETE BARRIERS

Number of Lanes		Number of Studies	Capacity Range (vphpl)	Average Capacity	
Normal	Open			vph	vphpl
3	2	7	1,780-2,060	3,720	1,860
2	1	3	--	1,550	1,550

Source: Table 6-3 in the 1985 Highway Capacity Manual (5)

Capacity estimates were needed for both of the traffic-control options being evaluated for the US-59 Southwest Freeway project. For the first option, in which the same number of lanes was maintained but lane widths were narrowed, capacity estimates were needed for all three phases of construction. The capacity reductions during Phase I were on the frontage road where two narrow lanes were maintained. The capacity of the frontage road links through which the screen line passed was controlled by the signalized intersections at the downstream end of the links. The capacities of those intersections were estimated using Chapter 9 of the 1985 Highway Capacity Manual (5).

Phases II and III of the first option involved minor capacity reductions on the freeway due to narrow lane and shoulder widths. In the inbound direction, the screen line was located upstream of the freeway bottleneck location (between the Westpark entrance ramp and I-610) which controlled the volume that could actually pass through the freeway screen line link. Previous data collection and simulation studies of the Southwest Freeway indicated that the freeway capacity entering the bottleneck location was approximately 2,000 vphpl. The reduction in capacity due to the narrow lane and shoulder widths could be as much as 10 percent (or 1,800 vphpl), based upon the Highway Capacity Manual (5) adjustment factors for restricted lane width and lateral clearance. For the second option, a long-term lane closure reducing the number of lanes at the screen line from 3 to 2 in each direction, the capacity of 1,800 vphpl (which falls within the range reported in Table 1) was also used.

Is the Construction Zone Capacity Adequate?

In order to determine whether the construction zone capacity is adequate to accommodate the traffic demands normally served by the freeway, operational MOEs (level of service, average speeds, or delays) should be estimated for each traffic-control option. If a traffic-control option provides an acceptable level of service through the construction zone, then the travel impacts probably would be restricted to the freeway, and the evaluation could proceed directly to the estimation of operational and economic MOEs. If the level of service is unacceptable and good alternative routes are available, then it is likely that traffic will divert from the freeway and a corridor-wide evaluation should be conducted.

Operational MOEs may be estimated using any of several analysis tools: (1) highway capacity analysis procedures, (2) a work zone lane closure simulation model, or (3) a freeway simulation model. Highway capacity analysis procedures (5) are relatively easy to use but can provide level-of-service estimates only. QUEWZ (14) was developed for the Department to perform queue and user cost evaluations of freeway work zone lane closures. FREQ (15) is the freeway simulation model that has traditionally been used by the Department for evaluating freeway operations. Table 2 summarizes the capabilities of the three procedures for estimating operational MOEs in construction zones. The capabilities of other models, such as FHWA's CORFLO model, are reviewed elsewhere (12).

Typically, highway capacity analysis results would have to be fed into QUEWZ or FREQ in order to estimate average speeds, delays, and the corresponding road user costs. QUEWZ outputs additional road user costs; whereas, with FREQ, manual calculations must be performed to compute user costs from the delay and fuel consumption estimates which are reported by the model. The main limitation of QUEWZ is that it can evaluate only one freeway link at a time, although the capability to model multiple freeway links and ramps may be added to the next version of the model. FREQ currently has the capability to model multiple freeway links over multiple time periods, a capability which is almost essential when evaluating complex urban freeway construction zones.

TABLE 2. CAPABILITIES OF ANALYSIS TOOLS FOR EVALUATING TRAFFIC CONDITIONS IN CONSTRUCTION ZONES

CAPABILITY	Highway Capacity Analysis	QUEWZ	FREQ
Estimate Level of Service	Yes	No	No
Estimate Average Speeds	No	Yes	Yes
Estimate Queue Lengths and Delays	No	Yes	Yes
Estimate Additional Road User Costs	No	Yes	No
Evaluate Interactions Among Multiple Freeway Links and Ramps	No	No	Yes
Evaluate Multiple Time Periods	No	Yes	Yes

For the US-59 Southwest Freeway project, operational MOEs were estimated for both traffic-control options that were being considered. The Department estimated the additional road user costs for the traffic control plan it implemented, which was the first option in the demonstration study (16). For the Phase I construction on the frontage roads, highway capacity analysis procedures (5) were used to estimate the delays at all signalized frontage road intersections before and during construction, based upon the assumptions that traffic demands would be the same before and during construction and that delays between intersections would be minimal. For Phases II and III, which involved freeway mainlane construction, the FREQ8 (15) freeway simulation model was used to estimate delays to freeway traffic. Existing geometrics and traffic demands were simulated to estimate before-construction delays. Then, the model was revised to simulate during-construction conditions and estimate during-construction delays for each phase. The revisions included (1) reducing freeway segment capacities to reflect the effect of narrow lane and shoulder widths, and (2) relocating ramps as indicated in the traffic control plans. The additional vehicle-hours of delay attributable to construction were computed as the difference between the during- and before-construction delays. The increase in road user costs during construction was estimated by multiplying the vehicle-hours of delay by the average vehicle occupancy rate and the dollar value of time. The estimated average additional delay was more than 16,000 vehicle hours per day which translated into \$183,000 in additional road user costs per day (in 1987 dollars). These estimates represent approximately 5 minutes of delay and \$1 of additional cost per vehicle using the freeway. The delays are not excessive, compared to experiences at projects in other parts of the United States; however, they are likely to prompt some diversion away from the freeway especially during peak demand periods. Therefore, an evaluation of corridor-wide impacts seems appropriate and, in fact, was undertaken by the Department.

FREQ10PC (17), a more recent version of FREQ, was used to evaluate the second traffic-control option for the US-59 Southwest Freeway project (i.e., the long-term closure of one mainlane in each direction). As one might expect, the additional delays (assuming no diversion from the freeway) were extremely large and, in fact, exceeded the maximum values that could be reported by the model. Therefore, as part of the demonstration study a corridor-wide evaluation was performed to determine whether adequate unused capacity was available elsewhere in the corridor to permit a long-term lane closure on the freeway.

Compare Corridor-Wide Volume and Capacity

If the capacity through the construction zone is inadequate, then corridor-wide traffic volumes and capacities should be compared to determine whether the available capacity on alternative routes and modes in the corridor could compensate for the reductions in capacity on the freeway. The comparison of volumes and capacities should be made at critical screen lines.

The recommended procedure is to estimate a v/c ratio for the corridor at the screen line locations. This screen line v/c ratio provides a preliminary indication of how much excess capacity exists in the corridor and a reference point for comparing conditions before construction with conditions under alternative traffic-control options during construction.

Generally, a v/c ratio should be computed for the a.m. peak hour in the inbound direction and p.m. peak hour in the outbound direction. If off-peak short-term lane closures are being considered, then the highest volume off-peak hour should also be analyzed. The peak hour in each direction should be determined by summing the 15-min directional volume counts across the screen line and identifying the four consecutive 15-min periods with the highest total volume.

The screen line v/c ratio is computed as follows:

$$\frac{v}{c} = \frac{\text{total peak hour directional screen line volume}}{\text{total estimated directional screen line capacity}}$$

Table 3 provides a form for computing the screen line v/c ratio. The volume count for the corridor-wide peak hour should be entered for each route. The total peak hour directional screen line volume is the sum of the link volumes for all routes. Similarly, the capacity of the link through which the screen line passes is entered in column 3 for each route. The total estimated directional screen line capacity is the column 3 total. Column 4 is the v/c ratio for the screen line link of each route. The screen line v/c is the column 2 total divided by the column 3 total. Column 5 is the excess capacity at the screen line link for each route (i.e., the difference between the link capacity and the link volume).

TABLE 3. FORM FOR COMPUTING THE SCREEN LINE V/C RATIO FOR A CORRIDOR

(1) Route	(2) Link Volume (vph) v_i	(3) Link Capacity (vph) c_i	(4) Link v/c Ratio v_i/c_i	(5) Excess Capacity (vph) $c_i - v_i$
Route 1	v_1	c_1	v_1/c_1	$c_1 - v_1$
Route 2	v_2	c_2	v_2/c_2	$c_2 - v_2$
...
Route i	v_i	c_i	v_i/c_i	$c_i - v_i$
...
Total Screen Line	Σv_i	Σc_i	$\Sigma v_i / \Sigma c_i$	$\Sigma c_i - \Sigma v_i$

The link capacity is defined as the number of vehicles that can exit the downstream end of the link. The ends of freeway links are defined by ramps junctions, and the ends of frontage road and arterial street links are defined by controlled intersections (typically signal-controlled but occasionally stop-controlled). In most cases, the capacity calculations for freeway links and signal-controlled intersections are straightforward applications of Highway Capacity Manual procedures (5). There are, however, two cases in which it would be inappropriate to use Highway Capacity Manual procedures to compute the capacity of the downstream end of the link. First, if the freeway link is operating at level of service F (i.e., queuing from a downstream bottleneck extends into the link), then the number of vehicles that can exit the downstream end of the link is constrained by the queue, not by the capacity of the link itself, in which case the observed volume count is probably the best estimate of the number of vehicles that can actually exit the downstream end of the link. Second, if the downstream end of an arterial street link is stop-controlled, then the actual peak hour volume should also be used as the estimated capacity. In this second case, one would generally not want diverted traffic using a street with stop-controlled approaches, and setting the volume equal to the capacity indicates that no unused capacity is available for diverted traffic on such a route (unless the stop signs are removed).

A screen line analysis was performed to determine the v/c ratio for the US-59 Southwest Freeway corridor during the a.m. peak hour. The analysis included routes from Westheimer to Bissonnet. Table 4 summarizes the results of the screen line analysis of conditions before construction. It should be noted in Table 4 that the freeway capacity equals the screen line volume. As indicated earlier, the screen line is located upstream of the freeway bottleneck location in the inbound direction, and the freeway volume at the screen line is constrained by queuing from that bottleneck.

TABLE 4. US-59 SOUTHWEST FREEWAY CORRIDOR SCREEN LINE ANALYSIS: BEFORE-CONSTRUCTION CONDITIONS

<i>Route</i>	<i>Link Volume (vph)</i>	<i>Link Capacity (vph)</i>	<i>v/c Ratio</i>	<i>Excess Capacity (vph)</i>
<i>Westheimer</i>	4,339	4,800	0.90	461
<i>Richmond</i>	2,271	3,104	0.73	833
<i>Westpark</i>	3,069	3,360	0.91	291
<i>Southwest Freeway</i>	4,550	4,550	1.00	0
<i>Frontage Road</i>	1,244	1,880	0.66	636
<i>Bellaire</i>	1,595	2,560	0.62	965
<i>Bissonnet</i>	1,627	1,870	0.87	243
<i>Total</i>	18,695	22,124	0.85	3,429

Table 5 shows how the peak hour was identified. Figure 6 illustrates the calculation of link capacity for Westpark, which is a typical arterial street link whose upstream and downstream ends are defined by signal-controlled intersections.

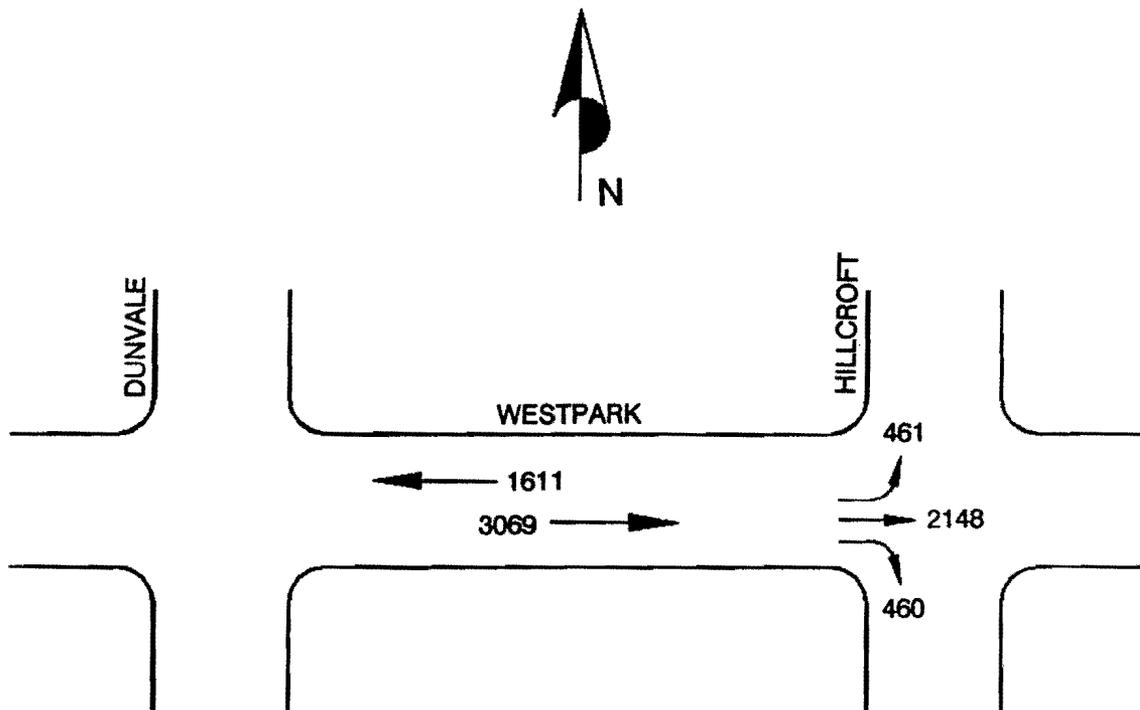
The results in Table 4 indicate a screen line v/c ratio of 0.85. This v/c ratio is relatively high, which is part of the reason the reconstruction project was undertaken to add capacity to the Southwest Freeway. Excess capacity in the corridor at the screen line is estimated at 3,429 vehicles during the a.m. peak hour. The calculation of excess capacity is based upon a v/c ratio of 1 on the approaches to the signalized intersections at the downstream ends of the links. Since operations at a v/c ratio of 1 are very poor, some percentage (perhaps 5 to 10 percent) of the excess capacity should be considered unusable.

Is the Corridor-Wide Capacity Adequate?

If the total corridor-wide capacity appears to be adequate, then a sound construction zone traffic control plan and an effective public information program may be sufficient to provide acceptable traffic flow throughout the corridor. In this case, the evaluation could proceed directly to the estimation of the changes in travel patterns in the corridor. If the total corridor-wide capacity appears to be inadequate, then it may be necessary to either change traffic-control options or develop a corridor traffic management plan by implementing traffic management techniques to mitigate the impacts of the option being considered.

TABLE 5. US-59 SOUTHWEST FREEWAY CORRIDOR A.M. PEAK HOUR DETERMINATION

TIME	Westheimer	Richmond	Westpark	Bellaire	Bissonnet	Freeway	Frontage Road	Total
6:00-6:15	137	61	203	65	37	1,065	44	1,612
6:15-6:30	209	96	271	132	85	1,513	42	2,347
6:30-6:45	379	169	483	192	178	1,322	164	2,887
6:45-7:00	768	291	657	293	266	1,220	230	3,724
7:00-7:15	829	319	723	377	308	1,237	276	4,068
7:15-7:30	1,054	491	817	355	424	1,197	339	4,677
7:30-7:45	1,099	638	866	481	451	1,049	335	4,919
7:45-8:00	1,144	663	721	407	400	1,162	327	4,823
8:00-8:15	1,042	479	665	352	352	1,142	243	4,275
8:15-8:30	1,021	479	721	331	285	1,164	281	4,281
8:30-8:45	803	338	665	265	243	1,168	155	3,637
8:45-9:00	666	300	654	272	195	1,157	174	3,417
Peak Hour Total	4,339	2,271	3,069	1,595	1,627	4,550	1,244	18,694



Downstream Intersection: Hillcroft

Capacity = $S \times N \times g/C$
 Adjusted Saturation Flow (S, vphgpl) = 1600
 Cycle Length (C, sec) = 100

	Through	Left	Total
Number of Lanes (N)	3	1	
Green Time (g)	65	34	
Capacity	3120	544	3664

Figure 6. Calculation of the Screen Line Link Capacity for Westpark

When interpreting a screen line v/c ratio, several points must be considered. The screen line v/c ratio provides an indication of conditions averaged over all routes across the corridor. The locations of bottlenecks on individual routes probably do not fall in a row along an individual screen line, and traffic conditions vary across and along the corridor. Excess capacity at a screen line may not be useful to diverted traffic if there are bottlenecks on the route upstream or downstream of the screen line location. Alternative route analyses must be performed to determine the amount of usable excess capacity along the length of each route. The quality of traffic flow in a corridor decreases as the v/c ratio approaches 1. A v/c ratio close to 1 probably indicates congestion on at least one route in the corridor. It is not possible to quantify the relationship between a screen line v/c ratio and the quality of flow throughout the corridor. However, the v/c ratios defining the level of service boundaries for freeways provide a frame of reference for judging the screen line v/c ratio. A v/c ratio of 0.77 is the lower boundary for level of service D, which "borders on unstable flow," and a v/c ratio of 0.93 is the boundary between level of service D and E which "describes operation at capacity" (5).

Table 6 summarizes the screen line analysis for the two traffic-control options. For the first option, which maintains the same number of freeway lanes through the construction zone as before reconstruction, the freeway link capacity at the screen line was reduced by 10 percent (from 4,550 to 4,095 vph). For the second option, the long-term closure of one lane in each direction, a freeway link capacity of 3,033 vph (2/3 of 4,550 vph) was used. Applying these percentage reductions to the observed freeway volume at the screen line assumes that a bottleneck will continue to exist downstream of the screen line during construction and that ramp demand patterns will remain the same. The results in Table 6 suggest that conditions in the corridor would not be much worse than normal if the same number of lanes was maintained through the construction zone, even with the minor capacity reductions due narrowing lane and shoulder widths. However, with a long-term lane closure and no improvements to alternative routes and modes, the corridor would be on the verge of capacity (0.91 v/c ratio). This v/c ratio is not so high, however, that the long-term lane closure option should be rejected without determining whether sufficient usable excess capacity can be developed on alternative routes in the corridor to accommodate the traffic that would have to divert from the freeway.

TABLE 6. US-59 SOUTHWEST FREEWAY CORRIDOR SCREEN LINE ANALYSIS: DURING-RECONSTRUCTION CONDITIONS

<i>Traffic-Control Option</i>	<i>Screen Line Volume (vph)</i>	<i>Screen Line Capacity (vph)</i>	<i>v/c Ratio</i>	<i>Unused Capacity (vph)</i>
<i>Maintain Same Number of Lanes</i>	<i>18,695</i>	<i>21,669</i>	<i>0.86</i>	<i>3,317</i>
<i>Long-Term Lane Closure</i>	<i>18,695</i>	<i>20,607</i>	<i>0.91</i>	<i>2,249</i>

This example illustrates the caution that must be exercised in interpreting the screen line analysis results. It must be remembered that the volume and capacity estimates apply only to one link on each route, and the excess capacity available on a route at the screen line may not be usable by diverted traffic. For example, Table 4 shows 636 vph of excess capacity on the frontage road, which was based upon the observed volume and the capacity of the frontage road approach to the downstream intersection (Hillcroft). However, the frontage road terminates downstream of the Hillcroft intersection and, therefore, the excess capacity may not be useful to traffic that would divert from the freeway. But, as part of Phase I of the actual traffic control plan, the frontage road is being extended beyond Hillcroft, and that capacity may become useful.

Revise Traffic Management Plan

If the corridor-wide capacity is not adequate to accommodate a traffic-control option, then traffic management techniques should be incorporated into the corridor traffic management plan to facilitate traffic flow through the construction zone or to make improvements to alternative routes and modes in the corridor. As detailed in Chapter 2, a corridor traffic management plan has three components:

1. The construction zone traffic control plan,
2. Corridor-wide impact mitigation techniques, and
3. A public information program.

Tables 7-9 summarize the techniques that were discussed in Chapter 2 for each of the three components. Table 7 provides a checklist of the traffic-control options and traffic management techniques to facilitate traffic flow through the construction zone. Table 8 lists the corridor-wide impact mitigation techniques that include improvements to alternative routes and techniques to increase public transit ridership and ridesharing. Table 9 summarizes techniques that might be included in a public information program for a reconstruction project.

Any of these techniques may be incorporated into the corridor traffic management plan to complement the traffic-control option selected. The techniques that are lowest in cost and easiest to implement should be considered first. The appropriate combination of techniques depends on project-specific conditions and constraints.

The corridor traffic management plan is built by incorporating traffic management techniques one at a time into a coordinated package. The extent of the package of traffic management techniques that is required to mitigate the impacts of reconstruction depends primarily on the severity of the capacity reductions on the freeway and the magnitude of the traffic demands that must be served in the corridor.

TABLE 7. CHECKLIST OF TRAFFIC-CONTROL OPTIONS AND TRAFFIC MANAGEMENT TECHNIQUES FOR CONSTRUCTION ZONE TRAFFIC CONTROL PLANS

<ul style="list-style-type: none"><input type="checkbox"/> Traffic-Control Options<ul style="list-style-type: none"><input type="checkbox"/> Maintain the Same Number of Lanes<input type="checkbox"/> Long-Term Lane Closures<input type="checkbox"/> Total Freeway Closures
<ul style="list-style-type: none"><input type="checkbox"/> Techniques to Facilitate Traffic Flow through the Construction Zone<ul style="list-style-type: none"><input type="checkbox"/> Portable Concrete Barriers<input type="checkbox"/> Paddle Screens<input type="checkbox"/> Narrow Lane Widths<input type="checkbox"/> Shoulder Use<input type="checkbox"/> Reversible Lanes<input type="checkbox"/> HOV-Only Lanes<input type="checkbox"/> Ramp Closures<input type="checkbox"/> HOV-Only Ramps<input type="checkbox"/> Incident Management Techniques

TABLE 8. CHECKLIST OF CORRIDOR-WIDE IMPACT MITIGATION TECHNIQUES

<ul style="list-style-type: none"><input type="checkbox"/> Improvements to Alternative Routes<ul style="list-style-type: none"><input type="checkbox"/> Traffic Signal Improvements<ul style="list-style-type: none"><input type="checkbox"/> Adjustments in Signal Phasing, Timing and Coordination<input type="checkbox"/> Improvements in Signal Equipment<input type="checkbox"/> Other Intersection Improvements<ul style="list-style-type: none"><input type="checkbox"/> Left-Turn Prohibitions<input type="checkbox"/> Additional Lanes<input type="checkbox"/> Police Officer Control<input type="checkbox"/> Other Roadway Improvements<ul style="list-style-type: none"><input type="checkbox"/> Reversible Lanes<input type="checkbox"/> One-Way Street Pairs<input type="checkbox"/> Pavement Marking Changes<input type="checkbox"/> Parking Prohibitions<input type="checkbox"/> Signing and Lighting Improvements<input type="checkbox"/> Pavement Improvements<input type="checkbox"/> Accelerated Maintenance
<ul style="list-style-type: none"><input type="checkbox"/> Techniques to Increase Public Transit Ridership and Ridesharing<ul style="list-style-type: none"><input type="checkbox"/> New or Expanded Bus Service<ul style="list-style-type: none"><input type="checkbox"/> New, Expanded, or Revised Routes<input type="checkbox"/> Additional Buses in Service<input type="checkbox"/> Improved Passenger Services<input type="checkbox"/> Preferential Treatment for Buses and HOVs<input type="checkbox"/> Improvements in Commuter Park-and-Ride Lots<input type="checkbox"/> New or Expanded Ridesharing Programs<input type="checkbox"/> New or Expanded Rail Service

TABLE 9. CHECKLIST OF PUBLIC INFORMATION TECHNIQUES

<ul style="list-style-type: none"><input type="checkbox"/> Traditional Public Information Tools<ul style="list-style-type: none"><input type="checkbox"/> Press Conferences<input type="checkbox"/> Media Events<input type="checkbox"/> Press Tours<input type="checkbox"/> Press Kits<input type="checkbox"/> News Releases<input type="checkbox"/> Public Service Announcements<input type="checkbox"/> Paid Advertising<input type="checkbox"/> Interviews<input type="checkbox"/> Public Meetings and Presentations <input type="checkbox"/> Special Publications<ul style="list-style-type: none"><input type="checkbox"/> Posters<input type="checkbox"/> Pamphlets<input type="checkbox"/> Newsletters<input type="checkbox"/> Maps<input type="checkbox"/> Special Mailings <input type="checkbox"/> Toll-Free Hotlines <input type="checkbox"/> Changeable Message Signs <input type="checkbox"/> Other Special Signing <input type="checkbox"/> Highway Advisory Radio <input type="checkbox"/> Ombudsman <input type="checkbox"/> Emerging Technologies
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Each potential alternative route should be analyzed to: (1) determine the traffic movements that it could serve, and (2) identify and evaluate the impact mitigation techniques that could facilitate those movements and, thereby, increase the amount of diverted traffic the route could accommodate. Referring back to the flowchart of the corridor analysis methodology in Figure 1, the alternative route analyses should consider the increases in corridor-wide capacity that can be produced, the changes in traffic patterns that can be served, and the operational and economic impacts that would result from improvements on the route.

Traditional traffic engineering analysis tools may be used to evaluate the operational and economic effectiveness of the techniques. For example, techniques to improve the capacity of the construction zone may be evaluated using highway capacity analysis procedures, a freeway simulation model (FREQ), or a work zone lane closure model (QUEWZ) as summarized in Table 5. Frontage road or arterial street improvements may be evaluated using intersection capacity analysis techniques or a signal timing optimization model such as PASSER II (19) or PASSER III (20).

Past experience indicates that the most motorists who divert from a freeway during a reconstruction project use an alternative arterial route in the corridor. Therefore, the amount of additional through traffic an arterial can accommodate is the key to its usefulness as an alternative route. Table 10 is a form for estimating the excess capacity for through traffic at each signalized intersection along an alternative arterial route. The data needed to perform the analysis include turning movement counts, intersection geometrics, and signal timing information. The existing through volumes at each signalized intersection along the arterial should be entered in column 2. The saturation flow rate for the through movement should be computed based upon the intersection geometrics using Highway Capacity Manual procedures and entered in column 3. The effective green time for the through movement and cycle length should be entered in columns 4 and 5, respectively. The effective green time is defined by the Manual as "The time allocated for a given traffic movement (green plus yellow) at a signalized intersection, less the start-up and clearance lost times for the movement" (5). The total through capacity is computed as follows:

$$c_T = s \times \frac{g}{C}$$

- where, c_T = total through capacity, vph
- s = saturation flow rate for the through movement, vphg
- g = effective green time for the through movement, sec
- C = cycle length, sec

The excess through capacity is computed as follows:

$$c_E = 0.95c_T - V_T$$

where, c_E = excess through capacity, vph
 c_T = total through capacity, vph
 V_T = existing through volume, vph

This equation indicates that the total through capacity should not be considered available for diverted traffic. Queue lengths and delays increase sharply as the v/c ratio on an intersection approach reaches 1. Therefore, to avoid oversaturated conditions, only 90-95 percent of the total through capacity should be considered potentially usable as excess capacity.

TABLE 10. FORM FOR COMPUTING EXCESS THROUGH CAPACITY ON AN ARTERIAL STREET

(1) Intersection	(2) Existing Through Volume (vph) V_T	(3) Through Saturation Flow Rate (vph) s	(4) Effective Through Green Time (sec) g	(5) Total Cycle Length (sec) C	(6) Total Through Capacity (vph) c_T	(7) Excess Through Capacity (vph) c_E
Int. 1	V_1	s_1	g_1	C_1	$s_1 * g_1 / C_1$	$0.95c_{T1} - V_{T1}$
Int. 2	V_2	s_2	g_2	C_2	$s_2 * g_2 / C_2$	$0.95c_{T2} - V_{T2}$
Int. i	V_i	s_i	g_i	C_i	$s_i * g_i / C_i$	$0.95c_{Ti} - V_{Ti}$

For the US-59 Southwest Freeway demonstration study, an analysis of one alternative route, Westpark, was performed to illustrate the methodology. Similar analyses should be performed for each alternative route. Table 11 summarizes the analysis of conditions on Westpark before construction. The capacity of the screen line link on Westpark is determined by its approach to Hillcroft. The speed profile for Westpark in Figure 4, which shows a relatively low average speed on the link, is consistent with the high v/c ratio reported for Westpark in Table 4. The amount of excess capacity is smallest at the Chimney Rock and S. Rice intersections (between US-59 and I-610), which had the lowest average link speeds in Figure 4. Since the inbound bottleneck on US-59 is between the Westpark entrance and I-610, Westpark is a potentially important alternative route between US-59 and I-610. Therefore, increasing the capacity of these two intersections could be a key to Westpark's usefulness.

TABLE 11. EXCESS THROUGH CAPACITY ON WESTPARK: BEFORE CONSTRUCTION

(1) Intersection	(2) Existing Through Volume (vph)	(3) Through Saturation Flow Rate (vph)	(4) Effective Through Green Time (sec)	(5) Total Cycle Length (sec)	(6) Total Through Capacity (vph)	(7) Excess Through Capacity (vph)
Briarpark	1349	3371	45	80	1896	452
Gessner	1254	3152	50	80	1970	618
Fondren	1526	4508	45	80	2536	883
Dunvale	1886	4542	68	90	3432	1374
Hillcroft	2148	4506	65	100	2929	635
US-59 SB Frontage Rd.	987	3172	36	60	1903	821
US-59 NB Frontage Rd.	1234	3395	36	60	2037	701
Chimney Rock	1335	3278	40	80	1639	222
South Rice	1144	3388	40	80	1694	465
I-610 SB Frontage Rd.	1637	3320	60	80	2490	729
Newcastle	946	3390	35	80	1483	463
Weslayan	366	3384	25	80	1058	639

Several traffic management techniques were considered for increasing the usable capacity for diverted traffic on Westpark. First, signal timing improvements were considered. PASSER II was used to optimize the signal timing along Westpark. The green splits were optimized, a range of cycle lengths was considered, and phasing alternatives and left-turn treatments at the bottleneck intersections were evaluated. In total, these signal timing improvements produced 100-200 vph of usable additional capacity for through movements along Westpark.

Another traffic management technique that the Department actually evaluated and selected for implementation was reversible lane operations on Westpark (21). The Department identified Westpark as an alternative to motorists particularly during one construction sequence in which the movement from the US-59 Chimney Rock entrance to I-610 would be restricted and during freeway incidents. The volume of traffic that might divert to Westpark was estimated based upon data from an earlier origin-destination study

in the corridor. A capacity analysis of the S. Rice intersection indicated that conditions would deteriorate to level of service F without the reversible lane. Whereas, the diverted traffic could be accommodated at level of service C (the same as before construction) with the reversible lane. Similar analyses were performed for the other intersections on Westpark. It was determined that reversible lane operations would be cost effective and should be implemented.

Other improvements to Westpark might also be evaluated, such as adding a lane on one or more approaches to the Westpark-Hillcroft intersection. Similar analyses should be performed for the other alternative routes.

In fact, several other impact mitigation techniques were evaluated and implemented by the Department, City of Houston Department of Transportation, and Houston METRO. An analysis of capacity and signal improvements throughout the corridor was performed. Plans to widen Beechnut were already being implemented. Signal equipment improvements were implemented to interconnect signal systems along Westheimer. A motorist assistance program to reduce incident response time within the construction zone was approved for implementation. A public affairs officer was assigned to the project, and an extensive public information program was developed that incorporated many of the techniques identified in Table 9.

Revise Corridor-Wide Capacity Estimates

The screen line v/c ratio analysis should be updated to reflect the increases in capacity associated with the traffic management techniques selected for implementation in the construction zone and on alternative routes and modes in the corridor. The screen line v/c ratio provides a common basis for comparing the corridor-wide impacts of various traffic-control options and traffic management techniques. However, the benefits of some techniques cannot be meaningfully quantified in terms of capacity increases, at least not at a screen line. For example, incident management techniques can produce substantial benefits by lessening the duration of capacity reductions due to incidents, however, those benefits cannot be meaningfully translated into a capacity increase at a screen line. In other words, the screen line v/c ratio is a useful evaluation tool, but it does not provide a complete assessment of the benefits of improvements. The screen line analysis of all routes across the width of the corridor and the analysis of alternative routes along the length of the corridor must be coordinated for a complete evaluation of travel impacts.

For example, Table 6 was updated to reflect the additional capacity that was developed along Westpark. The results are summarized in Table 12. With 200 vehicles of additional a.m. peak hour capacity on Westpark resulting from the signal timing improvements that were discussed, the screen line v/c ratios for both traffic-control options decreased by 0.01. Similar adjustments should be made for most of the other improvements discussed in the previous example. However, some of the improvements could not be translated into capacity increases at the screen line. For example, the Westpark reversible lane will increase capacity on a segment of Westpark downstream of the screen line and, therefore, that increase will not be reflected in the screen line v/c

ratio. However, the reversible lane makes the excess capacity available on Westpark at the screen line more useful since it eliminates the bottleneck at two downstream intersections.

TABLE 12. US-59 SOUTHWEST FREEWAY CORRIDOR SCREEN LINE ANALYSIS: DURING-CONSTRUCTION CONDITIONS WITH IMPROVEMENTS TO WESTPARK

<i>Traffic-Control Option</i>	<i>Screen Line Volume (vph)</i>	<i>Screen Line Capacity (vph)</i>	<i>v/c Ratio</i>	<i>Excess Capacity (vph)</i>
<i>Maintain Same Number of Lanes</i>	18,695	21,869	0.85	3,317
<i>Long-Term Lane Closure</i>	18,695	20,807	0.90	2,249

Estimate the Changes in Travel Patterns in the Corridor

Estimates of the changes in travel patterns that are likely in the corridor during reconstruction are essential to the development of an effective corridor traffic management plan. A key to predicting changes in travel patterns is an understanding of existing traffic movements in the corridor. That understanding may be based upon general knowledge of local conditions or, more formally, upon the results of an O-D study or select link analysis of the regional travel model. Reasonable predictions about how motorists might adjust their travel patterns are needed in order to identify which alternative routes or modes in the corridor might be affected and what traffic management techniques might effectively mitigate the adverse impacts of the reconstruction project.

Motorists have five basic choices for responding to the travel impacts of urban freeway reconstruction projects:

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

The cancellation of trips in the corridor is not a desirable response, at least from the perspective of businesses in the corridor. Experience at past projects suggests that it is an uncommon response, and the changes in total corridor volumes are likely to be minor. At past projects, the most common response by motorists who changed their travel patterns was spatial diversion. Temporal diversion has also been observed to have small, but beneficial, amounts of modal diversion.

Therefore, in conducting a corridor analysis to evaluate the techniques to include in a corridor traffic management plan, it should be assumed that the corridor must serve the same volume of traffic during construction as existed before construction. Some peak hour spreading and diversion to public transit and ridesharing modes is likely to occur, but it should not be assumed when evaluating alternative route improvements.

The analysis for Westpark, which was discussed in previous examples, illustrates how estimates of possible changes in travel patterns are incorporated into the evaluation of: (1) the role an arterial street could serve as an alternative route, and (2) the traffic management techniques that might be implemented to expand its role. Westpark was the focus of considerable attention in the demonstration study (and by the Department in reality) because its location with respect to major traffic generators in the corridor made it an attractive alternative route that could serve selected traffic movements. The traffic movements and volume of diverted traffic that Westpark might serve were estimated based upon an earlier O-D study in the corridor.

Estimate Operational and Economic MOEs

Operational and economic MOEs are needed to evaluate the effectiveness of the various elements of the corridor traffic management plan. Operational MOEs, including travel times and average speeds, and economic MOEs, particularly road user costs, are needed to compare the costs and benefits of the impact mitigation techniques.

Operational MOEs may be estimated using traditional traffic engineering analysis tools: highway capacity analysis procedures, freeway simulation models, and signal timing optimization programs. Standard procedures are also available to translate operational MOEs into estimates of road user costs (22). Typically, a traffic management technique would be judged to be cost effective if the estimated savings in road user costs exceeds the cost of implementing the technique.

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

The estimation of operational and economic MOEs is an integral part of evaluating and selecting the traffic management techniques to be incorporated into the corridor traffic management plan and, therefore, has been discussed in previous examples. The evaluation of implementing reversible lane operations on Westpark is a good example of the need to estimate operational and economic MOEs. Intersection capacity analysis

procedures were used to estimate the delays on Westpark with and without reversible lane operations. These delays were translated into travel time costs, based upon an assumed value of time obtained from the SDHPT's Highway Economic Evaluation Model (HEEM) (23), and vehicle idling costs, using the procedure specified in AASHTO's A Manual for User Benefit Analysis of Highway and Bus Transit Improvements (22). The results of the analysis indicated a benefit-to-cost ratio of at least 1.89-to-1. On the basis of this analysis, the Federal Highway Administration approved funding for the reversible lane operations.

Are the Impacts Acceptable?

If the travel impacts on individual routes in the corridor are unacceptable, then the corridor traffic management plan should be revised to incorporate additional impact mitigation techniques, or the traffic-control option should be eliminated from further consideration. If the plan is revised, it should be re-evaluated.

Determining whether or not the travel impacts of a reconstruction project are acceptable is a policy decision. It would be desirable to develop a corridor traffic management plan that could maintain the same quality of traffic conditions in the corridor as before construction. If the capacity reductions through the construction zone are minor, this goal can usually be achieved with a relatively modest package of impact mitigation techniques. If long-term lane closures are implemented, however, then a much more extensive package of traffic management techniques would be required; even with such a package it may be necessary to accept some decrease in the quality of traffic conditions.

Past experience has indicated that motorists expect and are willing to accept some inconvenience during reconstruction projects. They have proven to be remarkably adept at minimizing their own personal suffering. A key to their acceptance and ability to adapt, however, is an effective public information program that clearly communicates the importance and long-term benefits of the project and that provides accurate and timely reports on traffic conditions and travel alternatives in the corridor.

For the US-59 Southwest Freeway demonstration study, it would seem reasonable to judge as acceptable the impacts associated with the option to maintain the same number of lanes through the construction zone as were available before construction. The screen line v/c ratio would be only slightly higher during reconstruction. Furthermore, the evaluation of the traffic management techniques included in the corridor traffic management plan to mitigate the impacts on alternative routes suggests that these techniques would be effective. For example, the evaluation of Westpark indicates that with a reversible lane it could accommodate the predicted volume of diverted traffic without a significant decrease in level of service.

For a long-term lane closure through the US-59 Southwest Freeway construction zone, however, the travel impacts could not be judged as acceptable. Even after incorporating the capacity increases on Westpark, the screen line v/c ratio with a long-term lane closure indicates that the corridor would be on the verge of capacity.

Therefore, additional revisions to the corridor traffic management plan would be required in order to accommodate a long-term lane closure, and the impacts of these revisions should be determined before a final conclusion is drawn.

Finalize Traffic Management Plan

The methodology continues until the travel impacts associated with the corridor traffic management plan are deemed acceptable. If more than one traffic-control option were evaluated, it would be necessary to determine which option would minimize the total cost of the reconstruction project. The corridor analysis methodology would provide estimates of the traffic management and road user costs which would be added to the cost of actual construction with the options. The option with the lowest total cost should be selected.

When the reconstruction project begins and the corridor traffic management plan is implemented, traffic conditions should be monitored. The true test of the plan is how well it works during reconstruction. The effectiveness of the traffic management techniques should be evaluated. As necessary, the traffic management plan should be revised by adding, deleting, or modifying individual elements.

Traffic patterns and conditions are being monitored during the US-59 Southwest Freeway reconstruction project as part of Study No. 2-8-87/1-1108, "Traffic Pattern Assessment and Road User Delay Costs Resulting from Roadway Construction Options." The reconstruction project is scheduled for completion in 1992. At that time it will be possible to measure more accurately the actual traffic impacts of the corridor traffic management plan that was implemented.

4. SUMMARY

Planning urban freeway reconstruction projects involves tradeoffs between demands for roadway space to perform the required work and the need to accommodate traffic. The allocation of the limited available roadway space between these demands has significant cost implications. The best allocation is the one that minimizes the total cost of the project, which has three components: (1) the costs borne by the Department to plan, conduct, and inspect the project, (2) the additional road user costs borne by motorists throughout the affected freeway corridor, and (3) the social, economic, and environmental costs borne by neighboring businesses and residents.

This report provides guidelines on the development of a corridor traffic management plan to mitigate the adverse travel impacts of an urban freeway reconstruction project. Chapter 2 presents a catalog of the traffic-control options and traffic management techniques that might be incorporated in the plan. Chapter 3 outlines a corridor analysis methodology for identifying, evaluating, and selecting those options and techniques that would be appropriate and effective for a particular project.

Past projects have demonstrated the importance and value of a corridor-wide perspective in traffic management planning for urban freeway reconstruction projects. Experience at these projects indicates that a well planned, implemented, and communicated corridor traffic management plan can effectively mitigate the adverse traffic impacts of reconstruction projects and create positive public opinions about the responsible highway agency.

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