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16. Abstract

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CONSIDERATIONS IN DEVELOPING
A STRATEGIC ARTERIAL STREET SYSTEM

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in Urban Mobility

Sponsored By

Texas State Department of Highways and Public Transportation
in cooperation with the
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Federal Highway Administration

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

Center for Transportation Research
Bureau of Engineering Research
The University of Texas at Austin

November 1990

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
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

Symbol	When You Know	Multiply By	To Find	Symbol
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)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

VOLUME

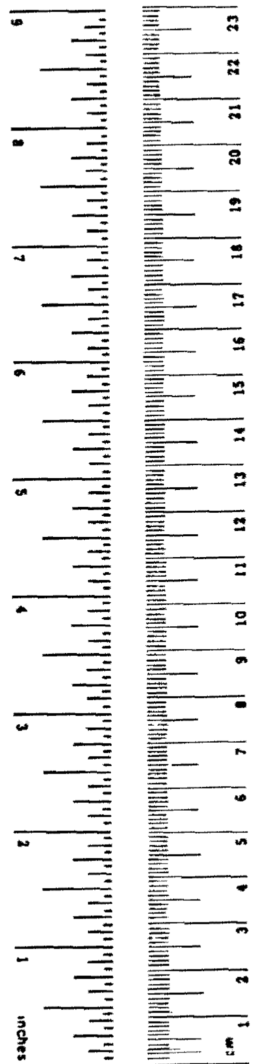
Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

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

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* SI is the symbol for the International System of Measurements



APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
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

Symbol	When You Know	Multiply By	To Find	Symbol
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

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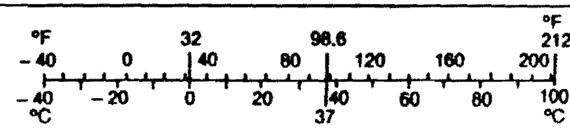

These factors conform to the requirement of FHWA Order 5190.1A.

ABSTRACT

Recently, attention has been directed towards the urban arterial street system to provide greater mobility, specifically in the form of a network of high-mobility arterial streets. These streets were named strategic arterials and would operate with greater capacity and operating speeds than current principal arterials, however, they would not fulfill the strict requirements of a freeway in terms of access control or right-of-way needs. Planning analyses demonstrated that capacity of the streets was the primary factor in causing diversion from a freeway system to a strategic arterial system. Design features associated with a strategic arterial should be different from ordinary arterial streets and identifiable by the motorist as being different. Several design criteria were identified. At-grade only improvements for a case study on an existing arterial resulted in limited increases in speed due to the highly congested nature of the area. Grade-separated improvements were needed to generate a speed that is near freeway speeds. A benefit/cost analysis of improving a 4-lane, urban city street to either a 6-lane, urban city street or a 6-lane strategic arterial demonstrated that the higher quality facility, even though more expensive, is a better investment. Implementation of strategic arterials will require strong local jurisdictional support, which will play a major role in the successful implementation of a strategic arterial network.

KEY WORDS:

Strategic arterial, arterial streets, planning, design criteria, mobility impacts, cost effectiveness, state role

SUMMARY

Recently, attention has been directed towards the urban arterial street system to provide greater mobility, specifically in the form of a network of high-mobility arterial streets. Expansion of freeway systems is becoming a less feasible option, due to cost, shortage of space, and environmental concerns. A network of upgraded arterial streets, in addition to freeways, may be suited to recent trends in urban area development--namely expanding suburban development which has resulted in higher dispersement of trip origins and destinations. Considering that the time frame within which usable segments of arterials can be upgraded is much shorter than that associated with freeway construction, use of arterial streets to provide urban mobility is becoming a more attractive alternative.

The concept of providing a system of higher-capacity arterial streets lead to the development of the term strategic arterial to describe arterials that serve an enhanced role. The proposed class of roads would operate at a level between existing principal arterials and freeways. These roads would have greater capacity and operating speeds than current principal arterials, however, they would not fulfill the strict requirements of a freeway in terms of access control or right-of-way needs.

Planning analyses demonstrated the potential for diversion from a freeway system to a strategic arterial system. The analyses used a 2010 highway network and associated travel data for the Houston-Galveston region. Three analyses were performed; each analysis used a constant trip table and one of the following networks: baseline network (no strategic arterials), 350 mile strategic arterial system, and 600 mile strategic arterial system. Changes in travel paths were determined by comparing the shift in vehicle miles traveled between the baseline condition and each strategic arterial system (350 mile and 600 mile systems) for the different facility types (freeways, strategic arterials, principal arterials, other arterials, and collectors).

In terms of the amount of daily vehicle miles travel shifted, freeways are the facility type most affected by a strategic arterial system. The 350 mile strategic arterial system caused over 3 million vehicle miles travel to be diverted from freeways to strategic arterials and the 600 mile

system caused over 5 million vehicle miles travel to shift. The strategic arterials possessed a 5 mph speed advantage and a capacity advantage over principal arterials. In terms of the effectiveness of strategic arterial systems, the planning analysis indicated that when implemented in heavily congested portions of an urban area, the capacity of the strategic arterial system will be the primary controlling factor with respect to the level of diversion of travel from other types of facilities to strategic arterials. The operating speed also influences the magnitude of travel on the strategic arterials.

Design features associated with a strategic arterial should be different from ordinary arterial streets and identifiable by the motorist as being different. Design features considered were a combination of the features associated with freeways and other arterials. These features result in a street that have some of the operating characteristics of both the freeway and arterial street. Below are some of the design criteria identified:

- design speed for strategic arterials between 40 and 60 mph
- most of the left turn maneuvers eliminated or redirected
- access management required to control traffic friction and accidents
- control of left turns and access preferably through continuous median barriers to increase the safety of the arterial, and provide driver guidance
- shoulders and/or speed-change lanes to enhance capacity and reliability of operations
- when traffic signals are present, the majority of the available green time allocated to the strategic arterial to maintain capacity and speed
- grade separations are used when crossing traffic cannot be accommodated by the allocated green time without compromising traffic operations on strategic arterial
- one-way street pairs can be effective strategic arterials by removing the conflict between left-turning vehicles and opposing traffic
- route continuity and minimum segmental lengths of 4 to 6 miles

Operational issues for a designer to consider when selecting improvements include whether at-grade improvements (e.g. turns bays, additional through lanes, prohibiting left turns) will provide the desired level of service or whether grade-separated improvements are needed; the quantity, location, and orientation of grade-separated structures; the number of signalized intersections per mile and spacing consistency; and the procedure to handle left turns. Simulation runs illustrated the important effects that signalized intersection spacing, left turn restrictions, and the location and orientation of grade-separated structures have on the average through speed of an arterial.

A case study illustrated the impacts on an existing arterial facility that at-grade and grade-separation improvements have on mobility. The simulation indicated that several at-grade only improvements such as the removal of two signals to improve intersection spacing, prohibiting left turns, and adding through lanes can improve overall mobility, however, grade separations at major intersections were needed to improve the average through speed to above 45 mph.

The Highway Economic and Evaluation Model (HEEM) was used to calculate a benefit/cost ratio and a measure of mobility (average speed) for two proposed improvements to a 4-lane, urban city street. The existing facility was improved to a 6-lane, urban city street and to a 6-lane, strategic arterial with a signalized intersection every 2 miles. The benefit/cost ratio of the improved city street is 9.2 with 21.2 mph expected on the improved facility. The strategic arterial improvement resulted in a 12.0 benefit/cost ratio and a 41.5 mph average speed on the improved facility. The results demonstrate that the higher quality facility, even though more expensive, is a better investment.

Implementation of strategic arterials will require strong local jurisdictional support, which will play a major role in the successful implementation of a strategic arterial network. For strategic arterials to be successful and distinguishable from other classes of streets, design guidelines will need to be conscientiously interpreted and appropriately applied. To reach this ideal, the responsible highway agency and the appointed team of designers will need to pursue the strategic arterial concept with great vigor and determination, and the process will need political and administrative backing from the highest levels possible. The state highway authorities are best suited to play the role of controlling the development of a strategic arterial system.

IMPLEMENTATION STATEMENT

The Texas State Department of Highways and Public Transportation is investigating methods to provide additional roadway capacity for major traffic movements. One area being examined to provide increased mobility in urban areas is the arterial street system. This report summaries the findings from analyses that illustrate the potential mobility impacts of a strategic arterial street system and discussions on design criteria, cost-effectiveness, and state roles for a strategic arterial. Successful implementation of a strategic arterial network will be dependant upon local jurisdictional support. The responsible highway agency and the appointed team of designers will need to pursue the strategic arterial concept with great vigor and determination, and the process will need political and administration backing from the highest levels possible.

DISCLAIMER

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CHAPTER 1

INTRODUCTION

In the U.S., the automobile is the predominant mode of travel. Traditionally, the emphasis has been on supplying roadway capacity to serve the demand for automobile transportation. Major emphasis has been placed on the development of urban freeways, but the supply of these facilities alone have not been enough to cope with peak-period traffic and ever-increasing demands for urban mobility. Expansion of freeway systems is becoming a less feasible option, due to cost, shortage of space, and environmental concerns. Other options, including efforts to encourage increased use of transit, have not completely yielded the desired results, since the modal preference strongly favors private travel.

Recently, attention has been directed towards the urban arterial street system to provide greater mobility, specifically in the form of a network of high-mobility arterial streets. The goal is to construct new arterials or upgrade existing arterials to provide higher capacity and travel speeds than are normally found on arterial streets. A network of upgraded arterial streets, in addition to freeways, may be suited to recent trends in urban area development--namely expanding suburban development which has resulted in higher dispersement of trip origins and destinations. Also considering that the time frame within which usable segments of arterials can be upgraded is much shorter than that associated with either freeway construction or effecting a change in mode preference, use of arterial streets to provide urban mobility is becoming a more attractive alternative.

1.1 PROJECT OBJECTIVES

The initial objective of this project was to identify the potential of the present arterial street system and of an improved arterial street system in Texas cities. The initial report for this project ("An Enhanced Role for the Arterial Street System in Texas Cities" [1]) found that the freeway systems in Texas handle higher percentages of the daily vehicle-miles traveled than other U.S. cities studied and that the percentages of vehicle-miles traveled on principal arterials is less than in the other U.S. cities studied (see Table 1). This under utilization of arterials implies that arterial streets in Texas, if properly developed, can be expected to serve higher trip volumes and therefore reduce demands on the freeway system. The report concluded that a feasible means of providing additional roadway capacity for major traffic movements in the large urban areas of Texas is by increasing the capacity of the arterial street system.

Table 1. Summary of freeway and principal arterial travel relationships, 1986

Urban Area	Freeway DVMT (1000)	Arterial DVMT (1000)	Total DVMT (1000)	Fwy DVMT % of Total	Principal Arterial DVMT % of Total	Freeway & Principal Arterial DVMT % of Total
Outside Texas Avg.[1]	13,325	8,945	35,070	34	26	60
Congested Texas Avg.[2]	14,455	6,010	34,870	41	18	59

[1] Average value of 22 large U.S. cities located outside of Texas, generally in the south, southwest and west.

[2] Congested Texas average includes the following cities: Austin, Dallas, Fort Worth, Houston, and San Antonio.

Source: Reference 1.

The concept of providing a system of higher-capacity arterial streets lead to the development of the term strategic arterial to describe these arterials that are serving an enhanced role. Objectives of this project included demonstrating the following about the proposed strategic arterial streets:

- potential traffic diversions to a strategic arterial street system from the freeway system
- design considerations for a strategic arterial street
- improvements needed to create a strategic arterial street from an existing arterial street
- cost-effectiveness evaluation of a strategic arterial street
- potential state roles and policy issues

1.2 ORGANIZATION OF THE REPORT

This report is the final report for the "Role of the Arterial Street System in Urban Mobility" project. In addition to providing the overall study findings, it contains a summary of the previous reports. The reader is referred to the following four reports for additional details:

- Christiansen, D. L. and W. V. Ward. An Enhanced Role for the Arterial Street System in Texas Cities. FHWA/TX-88/1107-1. November 1988.
- Mullins III, J. A. and J. D. Benson. An Analysis of the Potential for Traffic Diversion to a Strategic Arterial System. FHWA/TX-90/1107-2. May 1990.
- Fitzpatrick, K., B. Rymer, and T. Urbanik. Mobility Impacts from Improvements to an Arterial Street. FHWA/TX-91/1107-3. November 1990.
- Kruger, T. J., C. E. Lee, R. B. Machemehl, and W. V. Ward. Design Guidelines and Other Considerations for Strategic Arterial Streets. FHWA/TX-91/1107-4. Draft Final Report. January 1991.

The project findings presented in this report are contained in 7 chapters. A brief summary of the material in each chapter follows:

Chapter 1 - Introduction: Presents background information on the project and the organization of the report.

Chapter 2 - Strategic Arterial Concept: Presents the general characteristics of the newly proposed class of strategic arterials.

Chapter 3 - Strategic Arterial Street System Planning: Discusses the results of an analysis of the effect strategic arterials have on travel demands.

Chapter 4 - Strategic Arterial Street Design: Presents design considerations for a strategic arterial street.

Chapter 5 - Strategic Arterial Street Operations: Discusses the mobility impacts from improvements to an existing arterial streets.

Chapter 6 - Cost Effectiveness of Strategic Arterial Street Improvements: Demonstrates a cost-effectiveness technique for evaluating the potential of implementing a strategic arterial street.

Chapter 7 - Texas State Role: Identifies state roles including policy issues for consideration by the Department.

CHAPTER 2

STRATEGIC ARTERIAL CONCEPT

2.1 FUNCTIONAL CLASSIFICATION

Considering a new class of roads that would operate at speeds that are higher than speeds typical for existing arterials, yet not be required to satisfy strict freeway access requirements, prompted a review of the current functional classification scheme. The American Association of State Highway and Transportation Official's (AASHTO) A Policy on the Geometric Design of Highways and Streets (commonly referred to as the Green Book) [2] provides a functional classification based on the character of service that the road provides. The two major considerations in classifying streets functionally are access and mobility.

The proposed class of roads should operate at a level between existing principal arterials and freeways. This new class would have greater capacity and operating speeds than current principal arterials, however, they would not fulfill the strict requirements of a freeway in terms of access control or right-of-way needs. Therefore, a modified functional classification scheme is proposed and is shown in Figure 1. Freeways, with the requirements of grade separation and total control of access, are shown in their own class. The next class is arterial streets which has a primary function of providing mobility but with access control that is not as restrictive as freeways. The remaining two groups are still collector and local streets.

The proposed arterial class is subdivided into three subclasses: strategic arterials, principal arterials, and minor arterials. The majority of the existing arterials currently categorized as a principal arterial would continue to be placed in that subclass. Roads in the new strategic arterial class would have stricter control requirements than the principal arterial subclass but not as extensive as the freeway requirements.

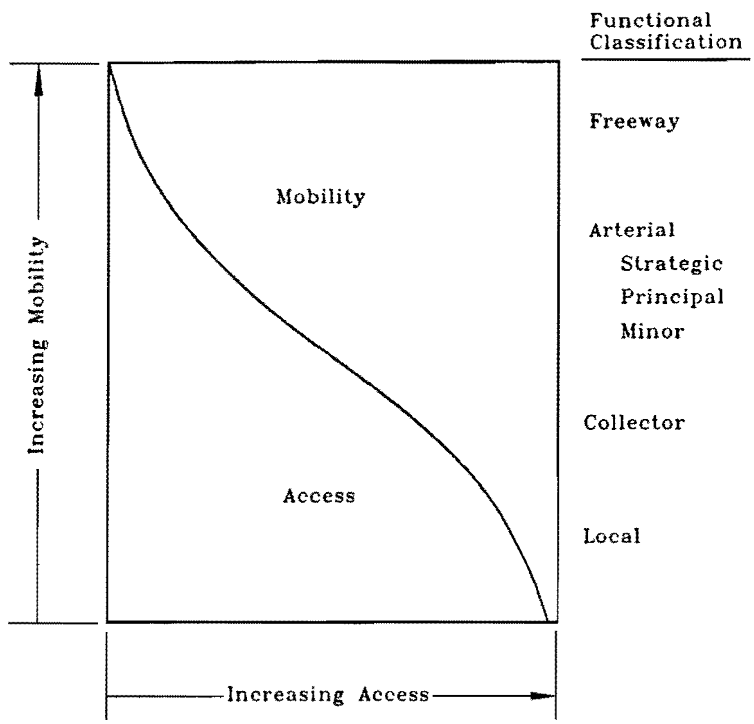


Figure 1. Proposed classification

2.2 CHARACTERISTICS

Characteristics describe how a road operates, functions, and/or appears. Characteristics can include items that will indicate if the road primarily provides access or mobility, the expected/typical operating speed along the facility, and the cross section of the facility (e.g., curbs or shoulders). Table 2 lists proposed characteristics of a strategic arterial along with characteristics of roads within other functional classifications. It illustrates how a strategic arterial fits within the existing classification scheme of roads.

The general characteristics of a strategic arterial should support its primary function of traffic movement. To support this function the arterial should have the following characteristics:

- Part of a system of regional, high-capacity arterial streets

Table 2. Functional route classification

Classification	Function	Continuity	Typical Spacing (miles)	Direct Land Access	Minimum Roadway Intersection Spacing	Operating Speed (mph)	Parking	Comments
Freeway and Expressway	Traffic Movement	Continuous	Greater than 4	None	1 mile	45 - 65	Prohibited	Provides high speed mobility
Strategic Arterial	Traffic Movement	Continuous	4	Rare	1/2 - 1 mile	40 - 55	Prohibited	
Primary Arterial	Intercommunity and intrametro area traffic movement	Continuous	1 - 2	Limited	1/2 mile	35 - 45 in fully developed areas	Prohibited	Backbone of street system
Secondary Arterial	Primary--intercommunity, intrametro area traffic movement Secondary--land access	Continuous	1/2 - 1	Restricted--some movements may be prohibited; spacing of driveways controlled	1/4 mile	30 - 35	Generally prohibited	
Collector	Primary--collect/distribute traffic between local streets and arterial system Secondary--land access Tertiary--inter-neighborhood traffic movement	Not necessarily continuous; should not extend across arterials	1/2 or less	Safety controls; limited regulation	300 feet	25 - 30	Limited	Through traffic should be discouraged
Local	Land access	None	As needed	Safety controls only	300 feet	25	Permitted	Through traffic should be discouraged

Source: Adapted from Reference 3.

- Continuity throughout the urban area from one facility to another of the same functional class or higher (strategic arterial or freeway) with a minimum length of 4 miles
- Minimum of 4-through lanes with adequate right-of-way for 6 lanes
- High design speed and operational flexibility
- Grade separations where applicable
- Long, uniform signal spacing
- Signalization improvements to facilitate progressive movement through the system
- Mid-block cross-section incorporating a non-traversable median and peripheral buffer strips
- Management of unsignalized median and peripheral access
- Pedestrian grade separations as needed
- No parking along street
- Consideration of transit loading and unloading areas
- Turn bays with adequate length for deceleration and storage when turning is permitted

CHAPTER 3

STRATEGIC ARTERIAL SYSTEM PLANNING

The implementation of a system of strategic arterials could, in many instances, provide alternative desirable travel routes for trips which would ordinarily use the State's freeway system. The potential for such diversion was the focus of the planning analyses undertaken as a part of this study. The urban travel demand models provide a useful framework for analyzing the potential traffic diversion to strategic arterial systems. The basic objective of the analyses was to assess, at a macroscopic level, both the potential demand on a proposed system of strategic arterials and the magnitude of the reduction in travel demands on the freeway system and the other portions of the arterial system. The analyses also demonstrated the use of the regional travel demand models for evaluating such systems and assessed the sensitivity of the travel demand models to input parameters describing the strategic arterials.

The principal data base used for the planning analyses was the year 2010 highway network and associated travel data for the Houston-Galveston region. The analyses focused on assessing the potential shifts in travel demand which could result from superimposing a system of strategic arterials upon the 2010 highway system for the region. The assigned volumes on the original 2010 system (without strategic arterials) was used as the baseline conditions and the analyses focused on the "shifts" in expected travel demands which resulted from superimposing the system of strategic arterials. By measuring the "shifts" in travel demand in terms of the changes in vehicle miles of travel (VMT) by facility type, the general nature of the "shifts" could be observed without focusing too much attention on link specific changes. Indeed, in implementing a system of strategic arterials, it is very likely that there will be instances where the strategic arterials will improve the accessibility to portions of the freeway system and, thereby, tend to increase the demand on portions of the freeway system while reducing the overall VMT on the freeway system. The VMT analysis allows a focus on the net changes in demand on the system by facility type rather than on individual links.

3.1 SYSTEM DESIGNATION

The designation of a system of strategic arterials for an urban area will largely focus on the identification of "key" arterials (existing and planned) which could be operationally improved to function as a system of enhanced arterials and not on the definition of an entirely new system of streets. Hence, a major portion of a strategic arterial system will already be represented in the baseline system and will be carrying significant volumes as was the case in the designation of the strategic arterial systems studied for the Houston-Galveston Region.

Two strategic arterial systems were delineated for study in the Houston-Galveston Region: a 350 mile system and a 600 mile system. The 600 mile system contains the 350 mile system plus 250 additional miles. Figures 2 and 3 illustrate the two systems delineated for study.

In the planning analyses, all strategic arterials were assumed to have a minimum 6-lane divided cross section. They would operate with a significantly higher percent green time which would result in higher capacities than those typically associated with arterials. It was also assumed in these analyses that strategic arterials would generally have a 5 to 10 mph speed advantage over principal arterials. Tables 3 and 4 list the speed and capacity values assumed in the analyses.

Given the assumption that a system of strategic arterials is generally comprised of existing facilities, the selected facilities in the data base were upgraded in terms of speed and capacity. In order to ensure adequate connectivity among the strategic arterial facilities comprising the system and particularly between the strategic arterial system and the remainder of the regional system, there was a need for a minor amount of designation of "new" facilities. However, this simply involved the extension of existing facilities from their baseline condition. Not surprisingly, the 600 mile system required more facility extension than did the 350 mile system.

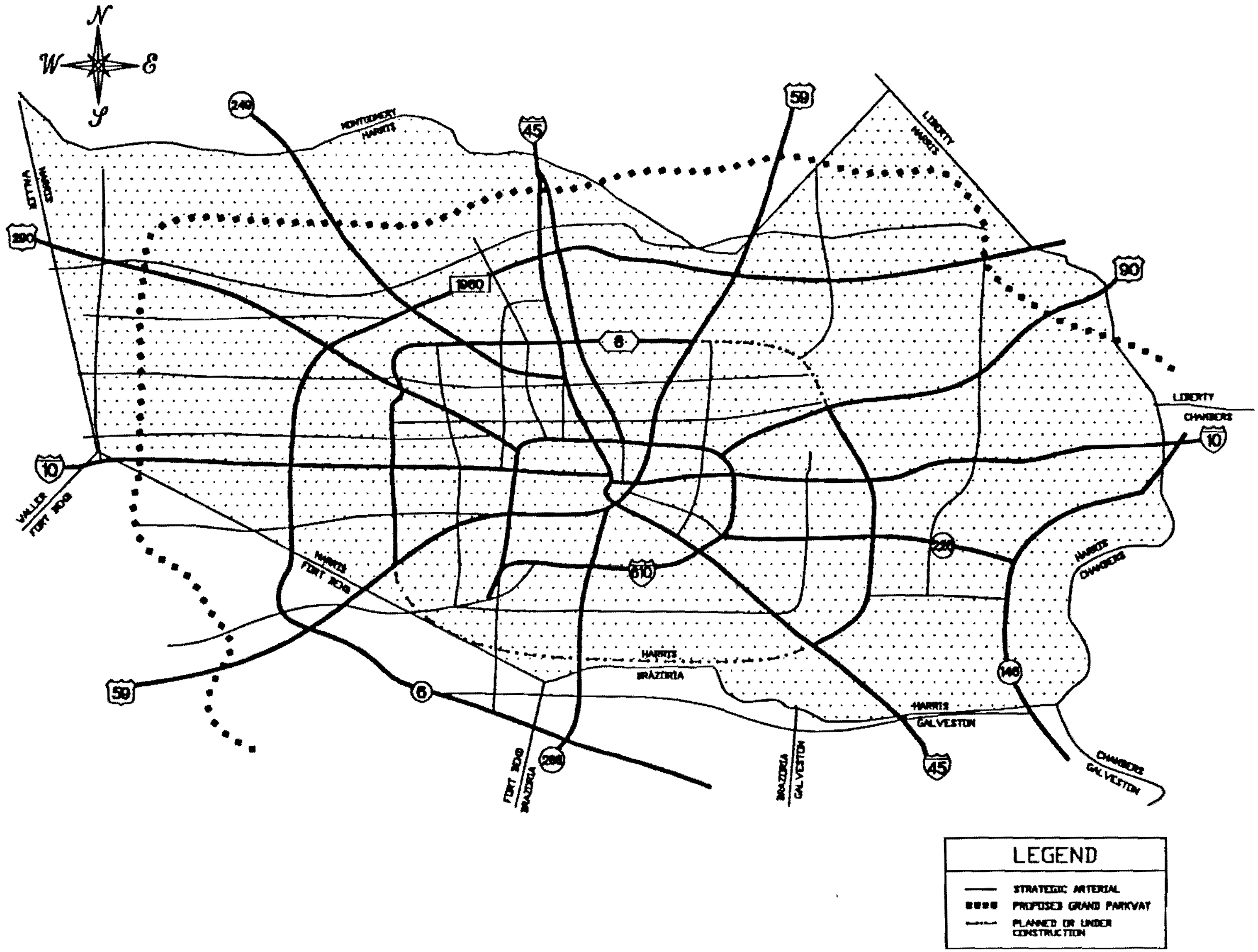


Figure 2. 600 mile strategic arterial street system.

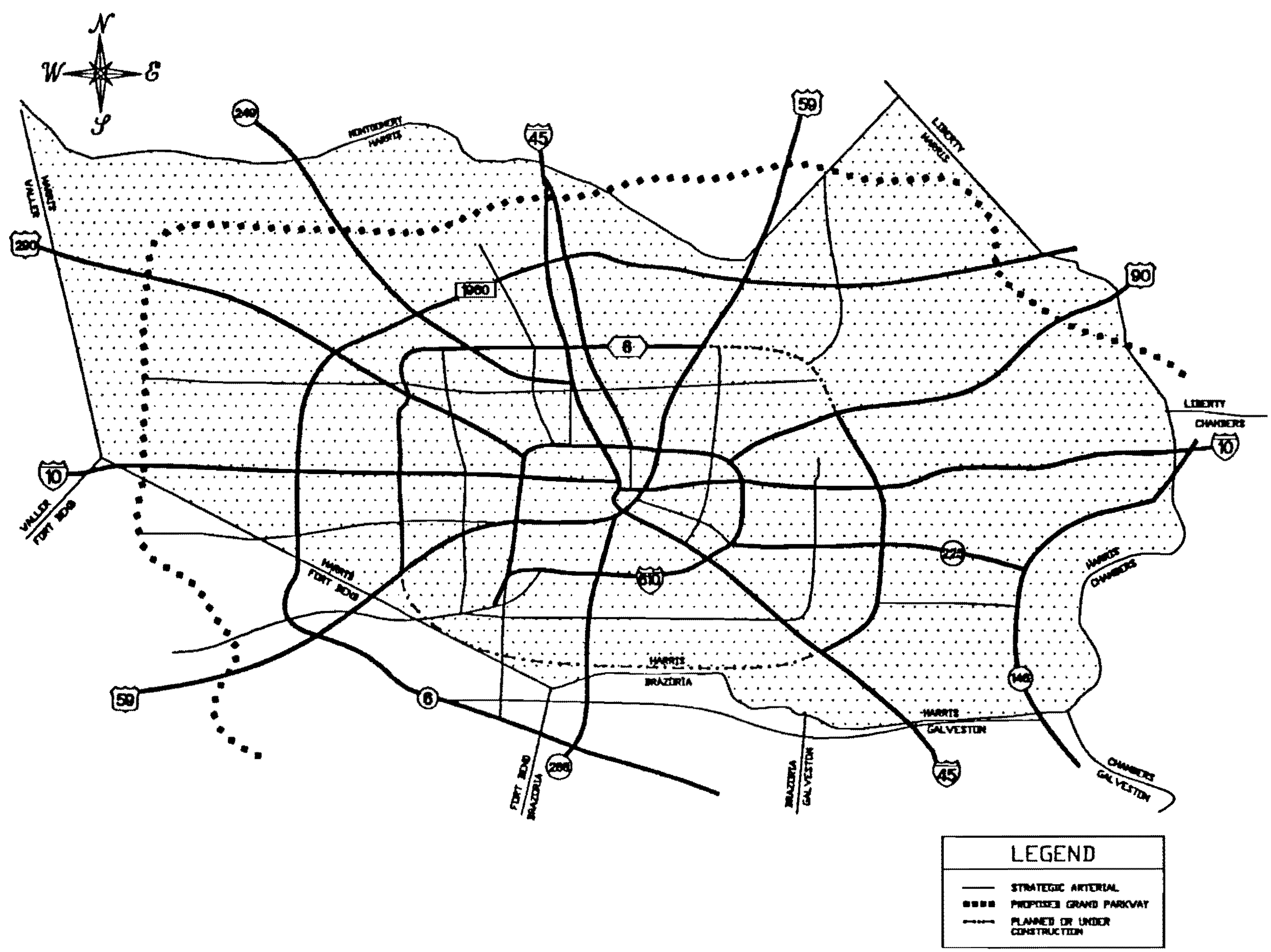


Figure 3. 350 mile strategic arterial street system.

Table 3. Speeds used in the analyses.

Facility Type	Area Type				
	CBD	Urban	Suburban	Fringe Suburban	Rural
Freeway	40	45	50	55	60
Principal Arterial	20	32	37	40	57
Strategic Arterial + 5 mph	25	37	42	45	57
+10 mph	30	42	47	50	57

Table 4. Capacities (24-hour) used in the analyses.

Facility Type	Area Type					
	Number of Lanes	CBD	Urban	Suburban	Fringe Suburban	Rural
Freeway	4	95,500	109,000	95,000	79,000	59,000
	6	132,000	155,000	136,000	113,000	82,000
	8	170,000	200,000	176,000	147,000	106,000
Principal Arterial	4	35,500	33,000	30,500	25,500	24,500
	6	50,500	47,000	43,500	36,000	35,000
	8	67,000	62,500	58,000	48,500	46,500
Strategic Arterial	6	65,500	60,500	56,000	46,500	38,500
	8	87,000	80,500	75,000	61,500	51,000

Table 5 presents a profile of the two strategic arterial systems used for study. The data show that a significant portion of the capacity increase of nearly 8 million VMT (77%) in the 350 mile strategic arterial system and nearly 15 million VMT (113%) in the 600 mile system was associated with an increase in the lane miles of strategic arterials. Lane miles of strategic arterials increased by nearly 30 percent in the 350 mile strategic arterial system and over 50 percent in the 600 mile system, relative to their base or "pre-upgraded" condition. Table 5 also

Table 5. Strategic arterial system profiles.

Facility Type	Centerline Miles	Lane Miles	Change from Baseline	System Capacity (VMT)	Change from Baseline
350 MILE STRATEGIC ARTERIAL SYSTEM					
Freeway	875.0	5,815.6		98,433,420	
Strategic Arterials	351.9*	2,157.2	488.5	17,830,725	7,786,371
Principal Arterials	446.5	2,040.8		13,729,146	
Other Arterials	2,546.1	8,827.8		50,065,064	
Collectors	2,351.7	5,009.9		17,027,140	
600 MILE STRATEGIC ARTERIAL SYSTEM					
Freeway	875.0	5,815.6		98,433,420	
Strategic Arterials	580.7**	3,530.3	1,215.2	28,103,990	14,903,606
Principal Arterials	440.2	2,015.9		13,576,756	
Other Arterials	2,428.0	8,353.1		47,537,259	
Collectors	2,294.6	4,863.5		16,551,305	

* Includes 14.5 miles of extended and 337.4 miles of upgraded facilities.

** Includes 62.3 miles of extended and 518.4 miles of upgraded facilities.

provides an indication of the minor effect on system-wide capacity related to the relatively insignificant level of facility extension (centerline miles). As can be seen from the two system profiles, there exist techniques for developing a system of strategic arterials which can result in significant increases in capacity without the designation of significant amounts of new facilities.

Only 14.5 miles of new facility were needed to complete the 350 mile system; a slightly larger amount, 62.3 miles, was delineated as part of the 600 mile strategic arterial system.

3.2 TRAVEL DEMAND ANALYSIS

Performance of the travel demand analysis was directed toward quantifying the potential for diversion associated with the implementation of a strategic arterial system by focusing on the "shifts" in travel demand on the various facility types of the regional system. By assigning the same baseline condition trip table to each of the strategic arterial systems, an analysis of the "shift" or change in travel paths (travel routes) can be performed. By holding the trip table constant, it is possible to gauge the effect of a strategic arterial system in terms of altering or "shifting" travel paths.

Table 6 presents the results of an assignment of the baseline trip table to each of the strategic arterial systems used for study. As the results show, both strategic arterial systems produced significant "shifts" in travel paths as shown by the change in VMT from the baseline (no strategic arterial system) condition. In terms of the amount of daily (24 hour) VMT, freeways are the facility type most affected by a strategic arterial system. It is important to note that the differences in the level of VMT diversion between the 5 and 10 mph speed conditions of an individual strategic arterial system are probably overstated. Most of the difference shown in Table 5 between the two speed conditions is likely due to the nature of the modelling procedure rather than a true difference in the diversion potential of the speed.

However, the significance of the increased level of travel path diversion (VMT "shifts") is that it appears not to be commensurate with the increase in the speed advantage of the strategic arterials. In other words, it might have been assumed that a doubling of the speed advantage of the strategic arterials would produce a similar change in the level of travel path diversion. The results of the analysis of the two strategic arterial systems do not follow this assumption. The level of diversion of freeway VMT resulting from the two strategic arterial systems will be used as an example. The 350 mile strategic arterial system caused over 3

Table 6. Strategic arterial system demand analysis results.

Facility Type	Baseline System Assigned VMT (w/o Strategic Arterials)	Strategic Arterial System Assigned VMT with a +5 mph Speed Advantage	Change in Assigned VMT from Baseline System	Strategic Arterial System Assigned VMT with a +10 mph Speed Advantage	Change in Assigned VMT from Baseline System
350 MILE STRATEGIC ARTERIAL SYSTEM - Travel Path Diversion					
Freeway	72,054,142	68,886,080	-3,168,062	67,886,661	-4,167,481
Strategic Arterial	7,878,995	13,755,484	5,876,489	15,576,475	7,697,480
Principal Arterial	9,823,801	9,188,269	-635,532	9,210,633	-613,168
Other Arterial	33,318,687	31,028,973	-2,289,714	30,416,677	-2,902,010
Collector	8,684,632	8,409,055	-275,577	8,361,953	-322,679
600 MILE STRATEGIC ARTERIAL SYSTEM - Travel Path Diversion					
Freeway	72,056,398	66,728,601	-5,327,797	65,269,252	-6,787,146
Strategic Arterial	10,172,464	19,064,896	8,892,432	21,514,562	11,342,098
Principal Arterial	9,731,642	9,052,612	-679,030	9,022,664	-708,978
Other Arterial	31,418,179	28,157,860	-3,260,319	27,546,432	-3,871,747
Collector	8,382,183	7,856,738	-525,445	7,800,436	-581,747

million VMT to be diverted from freeways to strategic arterials and the 600 mile system induced over 5 million VMT when the strategic arterials possessed a 5 mph speed advantage. When the speed advantage was increased to 10 mph, the level of freeway VMT diversion was increased by 1 million with the 350 mile strategic arterial system and by nearly 1.5 million with the 600 mile strategic arterial system. Certainly, these numbers are significant in their own right, but when viewed in the context of the diversion of freeway travel associated with the initial strategic arterial speed advantage, they seem somewhat small.

When reviewing the assignment results in detail, an explanation of the level of VMT diversion associated with the larger strategic arterial speed advantage is found. The explanation lies with the second aspect of the strategic arterial definition; strategic arterial capacity. The level of travel path diversion which could have been achieved by the 10 mph strategic arterial speed advantage was limited by the capacity of the strategic arterial system. The results show that a larger increase in diversion was achieved by the 600 mile strategic arterial system in the two speed conditions compared to the 350 mile strategic arterial system in the two strategic arterial speed conditions. The VMT diverted to the 350 mile strategic arterial system as a result of the initial 5 mph strategic arterial speed was of such magnitude that very little strategic arterial system capacity remained to accommodate additional VMT. Therefore, a relatively insignificant amount of the additional travel path diversion resulting from the higher strategic arterial speed could be accommodated. The 600 mile strategic arterial system was of sufficient capacity to allow a significant amount, although certainly not all, of the additional diversion caused by the larger strategic arterial speed advantage. Had strategic arterial capacity not been a consideration, the increase in strategic arterial speed advantage to 10 mph would have resulted in very significant increases in the level of travel path diversion associated with both of the strategic arterial systems. These analyses' results indicate that in this application the capacity of the strategic arterial system is a controlling factor in the level of travel path diversion associated with strategic arterial systems.

In addition to the "shifting" or diversion of travel paths resulting from a strategic arterial system, an analysis on the effect to travel patterns was performed. The results of the travel pattern analysis as well as a more detailed review of the information presented in this chapter along with the results of strategic arterial analyses conducted in the Dallas/Fort Worth region can be found in Research Report 1107-2 entitled "An Analysis of the Potential for Traffic Diversion to a Strategic Arterial System" [4].

3.3 SUMMARY

The results of this analysis suggest that there exist techniques by which a system of strategic arterials can be implemented to successfully reduce the level of congestion, particularly freeway congestion in heavily congested portions of an urban area. Furthermore, the analysis indicates that the successful implementation of such a system does not require the creation of an entirely new set of facilities.

In terms of the effectiveness of strategic arterial systems, the planning analysis indicates that when implemented in heavily congested portions of an urban area, the capacity of the strategic arterial system will be a controlling factor with respect to the level of diversion of travel from other types of facilities to strategic arterials. This is not to say, however, that the speed under which the strategic arterials operate is unimportant. Most certainly, the operating speed of these types of facilities will influence, in congested areas, the magnitude of travel on the strategic arterials. Undoubtedly, however, the key issue in determining the ability of a system of strategic arterials to divert travel from freeways and other facilities within a congested corridor is not the speed under which they operate but rather to what level of capacity that will be built.

CHAPTER 4

DESIGN CONCEPTS FOR STRATEGIC ARTERIALS

A primary distinction between strategic arterials proposed in this study and other arterials is the higher quality of service and the greater attractiveness of the strategic arterial. Higher quality service is related to such characteristics as travel speed, capacity, reliability of operations, proximity to trip origins and destinations (route location), and facilities that support the arterial (feeder streets). Speed, capacity, and reliability are primarily related to geometric design and access control. Proximity and supporting facilities are a function of route location, lane use, availability of rights-of-way, and the existing transportation network structure.

Design features associated with a strategic arterial should be different from ordinary arterial streets and identifiable by the motorist as being different. The design features discussed in the following sections are a combination of the features associated with freeways and other arterials. These features result in a street that has some of the operating characteristics of both the freeway and arterial street. Additional discussion is contained in another report from this project [5].

4.1 DESIGN SPEED

AASHTO in the Green Book [2] argues that for arterial streets, design speed control applies to a lesser degree than on other high-type highways. On arterial streets, the top speeds for several hours of the day are limited or regulated to that at which the recurring peak volumes can be handled. Speeds are governed by the magnitude of the arterial's volume, friction caused by midblock driveways and intersections, and traffic control devices rather than by the physical characteristics of the street. However, strategic arterials, with characteristics of both freeways and principal arterials, will have running speeds that are more influenced by the facility's design. Therefore, an important step in maintaining the high operational and geometric design standards of the strategic arterial class is in the selection of the arterial's design speed. Design speed is used in the design of the street's horizontal and vertical alignment, sight distance, and other items. Design speed for a major urban arterial highway depends largely on the frequency of at-grade intersections and the amount of cross and turning traffic. Other factors to consider include speed limits, physical and economic constraints, and the likely running speeds that can be attained during off peak hours. AASHTO recommends that the design speed for major urban arterial highways should be between 40 and 60 mph. With the operational requirements for strategic arterials, the design speed should be a minimum of 45 mph.

4.2 MANAGEMENT OF LEFT TURNS AND U-TURNS

Signalized intersections are a major influence on the capacity of an urban arterial. The allocation of green time for several movements limits the amount of reasonable green time available for any one movement. The elimination or redirection of left turns permits a reallocation of green time to better favor the strategic arterial's street through movement. Removing left turns along the arterial improves operations and enhances safety because the left hand lane does not have to slow for left turning traffic or be inconvenienced by the queuing for left turns. To facilitate signing and avoid driver confusion, a consistent method of managing left turns should be used at all intersections along an arterial, or in a consistent pattern over a long arterial section.

4.3 ACCESS MANAGEMENT

Land access is a major cause of traffic friction and accidents on arterial streets; therefore, access management will be required on strategic arterials. Although the only basic legal right of property owners is for access to a public road and not necessarily to the traffic it carries, control of access to any street is often highly political. While land-use control can and should be used to control access and to stabilize and enforce access management, it alone is not completely effective--its primary effect is realized only over the longer term. Another tool for access management that is more directly within the power of the highway authority is the establishment of geometric criteria within the right-of-way which control specific turning movements at driveways.

4.4 SIGNAL TIMING

When signalized intersections are necessary, the green time allocated to the strategic arterial should be substantially greater than that given to the crossing street. Because signal timing has significant influence on the capacity of an arterial, the majority of the available green time will need to be allocated to the strategic arterial.

4.5 MEDIAN TREATMENT

Median treatments are used to control access and left turns, increase the safety of a facility, and provide driver guidance. Medians on urban streets can either be a physical barrier or only consist of a painted area. They are generally installed to provide for the control or protection of crossover or turning movements or pedestrians. They can also convey to the driver an indication as to the road's classification. For example, a continuous concrete median barrier would indicate a high-type facility design rather than a collector or local street facility.

Continuous median barriers restrict left turns and remove the adverse effect of crossover movements in midblock areas. They also can redirect an errant vehicle from straying into opposing traffic. Wide physical median barriers (24 feet or more in width) may have some, but limited application to strategic arterials. Typically, a strategic arterial will be developed within limited right-of-way and the space for a wide median would probably be needed for additional travel lanes. Wide medians, where adequate right-of-way is currently available, could be used as an interim phase until the additional lanes are constructed.

Barrier types for consideration on narrow medians include curbs, concrete median barriers, and metal beam guard fences. Curbed medians are effective in controlling crossover movements but have little effectiveness in redirecting out-of-control or errant vehicles. Advantages of curbed medians include relatively low installation and maintenance costs and being more aesthetic than other types of physically barriers. The use of a continuous concrete median barrier lends itself to the concept of communicating the extraordinary nature of high mobility arterials because these barriers are not typically used on urban streets and are frequently used on freeways. A metal beam guard fence provides good control of midblock crossovers and can redirect errant vehicles. However, they have moderate aesthetic values and a higher level of maintenance when compared to concrete barriers.

4.6 LANE WIDTHS

Lane widths and lateral clearance to obstructions influence the quality of traffic operations. Lane widths of 12 ft are desirable for the highest possible level of service as is adequate lateral clearance. However, in a restricted location, 11-ft lanes may be an acceptable compromise.

4.7 SHOULDERS

Shoulders are not usually included on arterial streets. However, reliability of operations on a high-speed facility can be enhanced by the existence of the additional paved area. Shoulders provide space for emergency stopping, storm water (which can reduce the capacity of a curb lane), and maintenance operations. Shoulders are considered an integral part of freeway design and a similar addition to arterial streets should be very effective in improving traffic capacity, operational reliability, and safety.

4.8 SPEED-CHANGE LANES

The provision of a lane to facilitate the merging and diverging of vehicles from a development with access to the strategic arterial should improve the safety, capacity, and operations of the arterial. Speed-change lanes can minimize the speed differential between turning vehicles and the through lane vehicles. Speed-change lanes are also an integral part of freeway design.

4.9 CURBS

Curbs control drainage, delineate the roadway edge, deter vehicles from leaving the paved surface, and aid in channelizing vehicle movements. They control access to designated driveway locations and can assist in orderly roadway development. The curb type should be compatible with the relative high design speed, require minimal right-of-way, offer the maximum possible roadway delineation, and restrict access to designated driveways. The latter two objectives are well satisfied by barrier curbs. Barrier curbs, however, are not seen as compatible to facilities where the design speed exceeds 40 mph. Mountable curbs do not offer the clear designation of driveways and the function of restricting access. The use of semi-mountable type curbing could maximize the advantages of each of the previous types of curbing.

4.10 GRADE SEPARATIONS

Grade separations are needed when crossing traffic cannot be accommodated by the allocated green time. A three-level interchange may be necessary between intersecting strategic arterials if through traffic on both facilities is large. Ordinarily, a diamond interchange should have sufficient signal capacity to handle the non-grade separated through movement on strategic arterials. However, if the at-grade traffic requires too much of the traffic signal green time, to the detriment of the through traffic at an ordinary diamond interchange, then a three-level interchange may be needed. These can be planned and constructed in stages provided adequate rights-of-way are reserved along the arterials.

4.11 ONE-WAY STREETS

Either converting existing streets to one-way couplets or using existing one-way streets as sections of strategic arterials have very distinct advantages including removing the conflict between left-turning vehicles and opposing traffic, at street intersections and driveways. Green time for through traffic at traffic signals can be increased as phases for left turns become unnecessary. Most of the advantages of one-way street operations are directly related to the reduction of conflicting movements. The additional capacity, signal timing efficiency, and conflict reductions result in reduced travel time and delays. One-way operations also remove the need for two-way progression of traffic signals.

The disadvantages of a one-way street implementation are that traffic circulation and travel distances in the area may increase. Some businesses, especially those reliant on passing traffic, may be affected by the one-way operations.

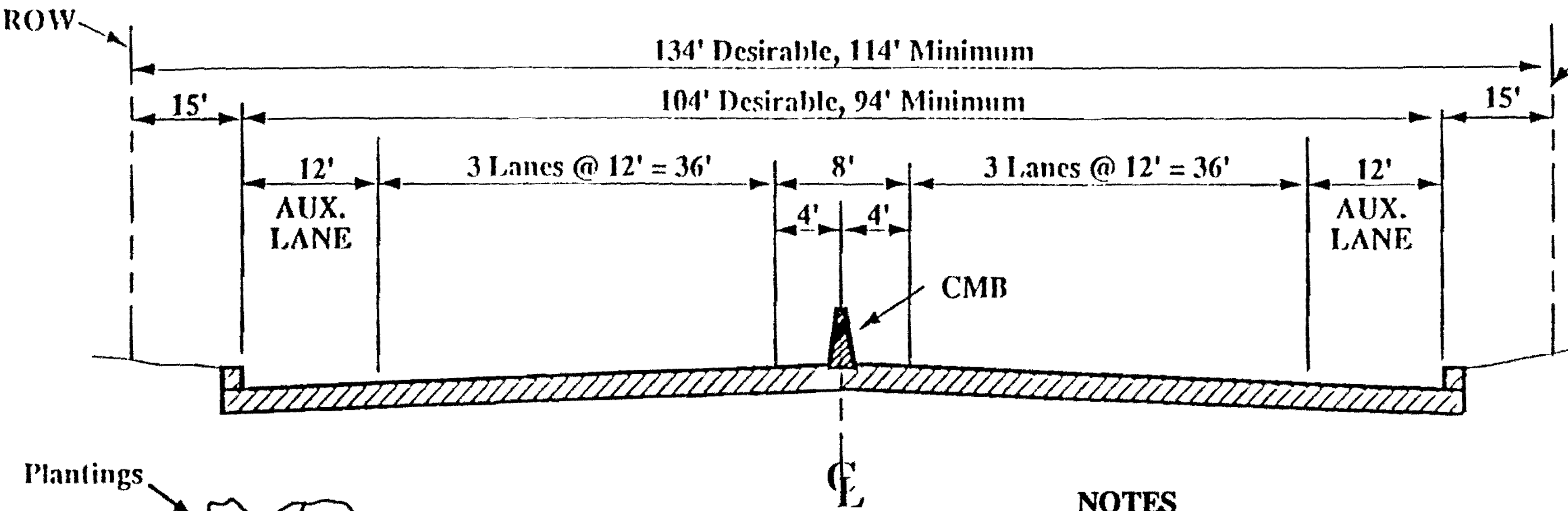
4.12 SIGNS

While signing on freeways is characterized by high quality, consistently applied signs, the quality of signing on arterial streets is subject to wide variations. With the use of grade-separated intersections and indirect left turns, which are not typical for urban arterials, high quality signing will be needed on strategic arterials. High quality and consistency in signs will assist in providing guidance to drivers and in communicating the high-speed nature of the facility.

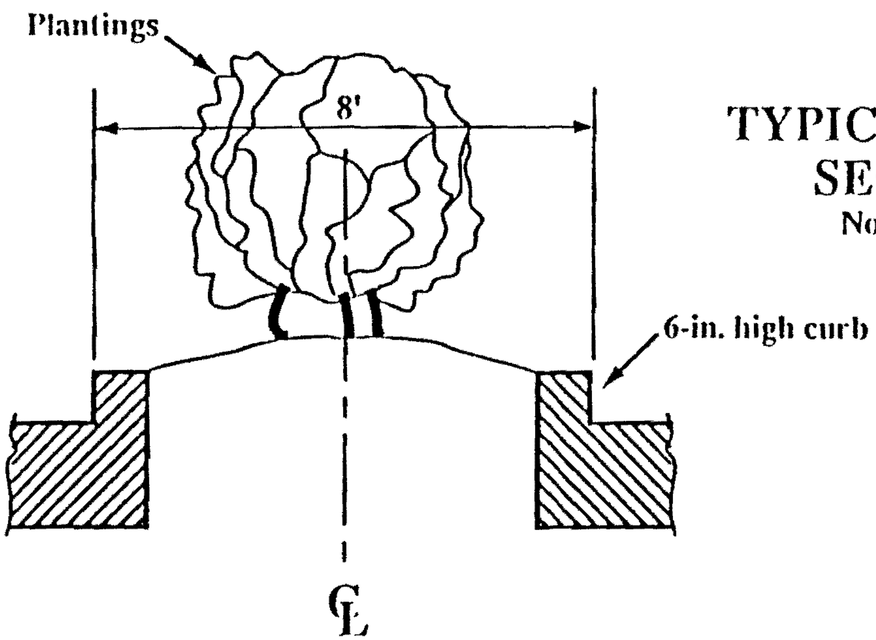
4.13 CONCEPTUAL DESIGNS

Figure 4 illustrates the proposed basic cross-section of a six-lane divided strategic arterial. This cross-section includes an auxiliary lane that can function either as an emergency parking shoulder or as a speed-change lane. Both shoulders and speed-change lanes are not usually included on arterial streets. The schematic also shows a concrete median barrier separating the opposing travel lanes. For this typical cross section, 134 ft is the desirable right-of-way width.

Figure 5 is a diagrammatic drawing showing operational movements that can be expected along a strategic arterial. If sufficient space between signalized intersections exists, the flow along the arterial between signalized intersections will be similar to a freeway. The signalized intersections accommodate the cross street traffic and the left and U-turns from the strategic arterials (that initially turned right from the strategic arterial on a jug-handle or ramp to the cross street). Figure 6 illustrates other methods of handling turning and crossing movements.



TYPICAL CROSS SECTION
Not to Scale



Alternate Median Design

NOTES

1. **Auxiliary Lane to function as Emergency Parking Shoulder or Speed-Change Lane**
2. **8-ft median desirable; 6-ft minimum**
3. **12-ft lane widths desirable; 11-ft minimum**
4. **15-ft ROW clearance desirable; 10-ft minimum**

Figure 4. Proposed typical cross section.

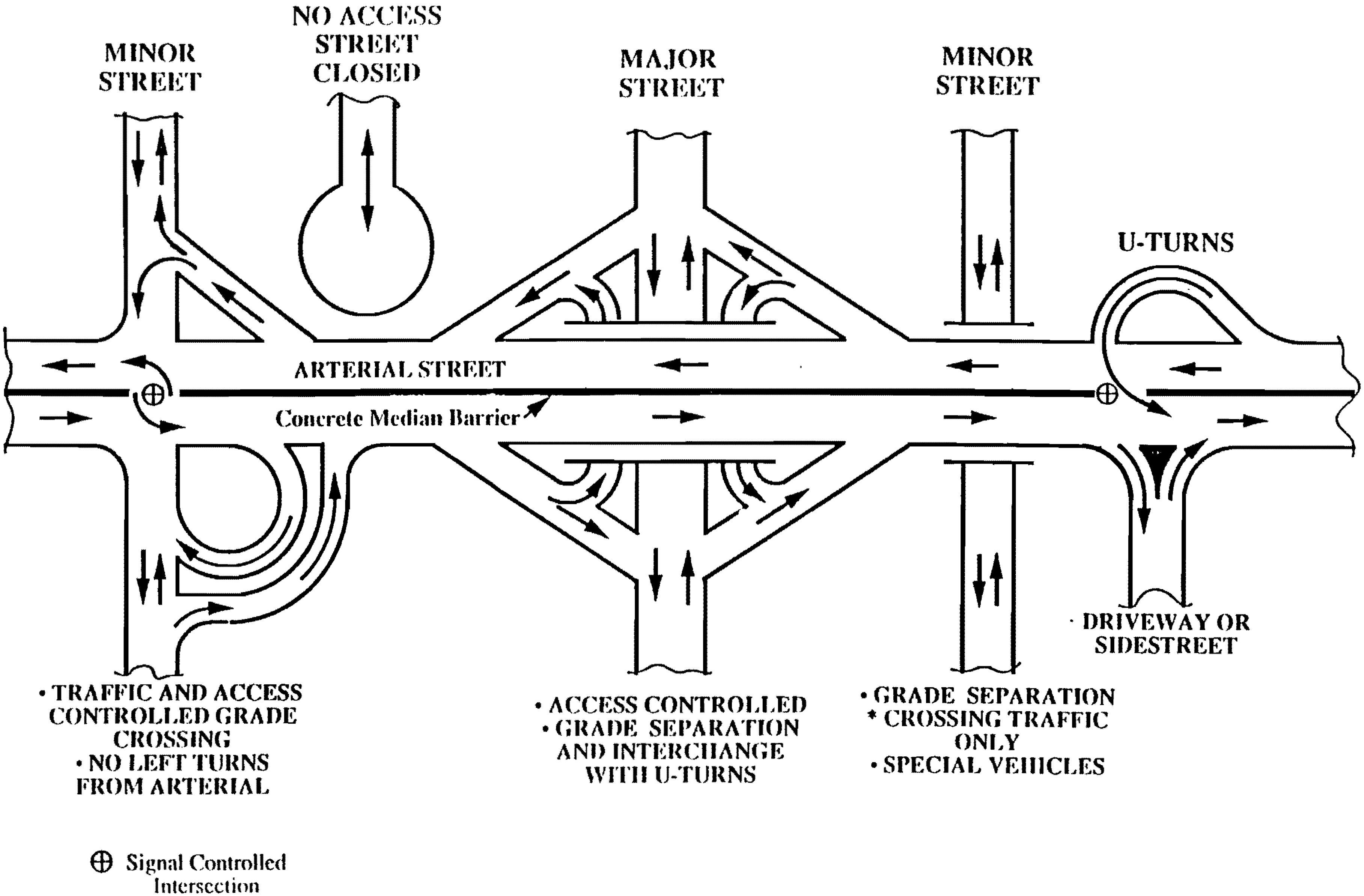


Figure 5. Strategic arterials special features.

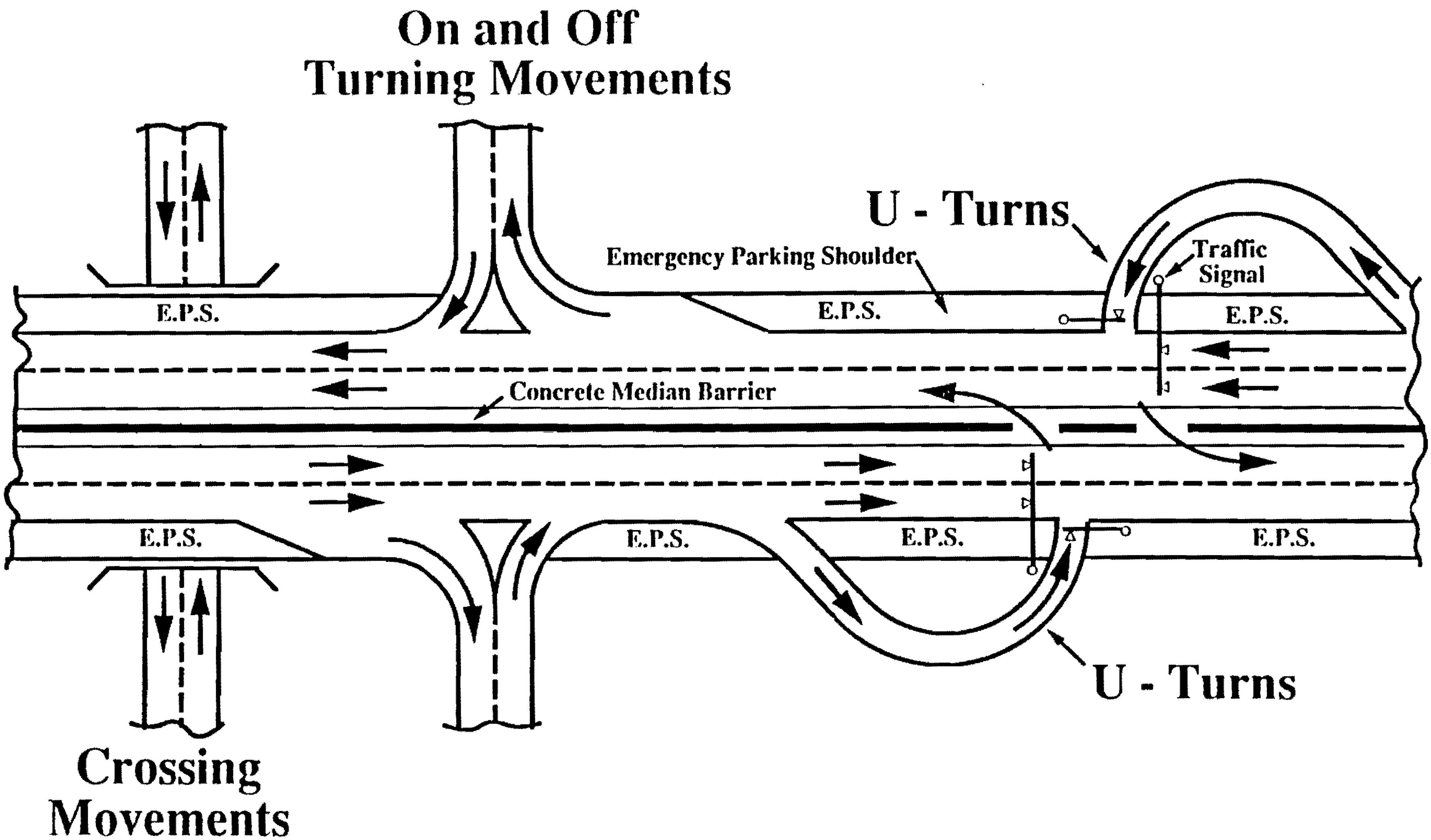


Figure 6. Separation of turning and crossing movements.

CHAPTER 5

STRATEGIC ARTERIAL STREET OPERATIONS

When implementing a strategic arterial street system, the decisions concerning the operations of the street should support the strategic arterial's primary function of traffic movement. The system's operation should also satisfy the other general characteristics of the functional class such as high operating speed and high level of service. These characteristics can be achieved using various operations-related improvements which would be selected by designers.

Operational issues for a designer to consider when selecting improvements include whether at-grade improvements (e.g., turn bays, additional through lanes) will provide the desired level of service or whether grade-separated improvements are needed; the quantity, location, and orientation of grade-separated structures; the number of signalized intersections per mile and spacing consistency; and the procedure to handle left turns.

This section provides a summary of the more important findings from simulation runs that illustrate the impacts at-grade and grade-separated improvements have on mobility. The reader is referred to the earlier report [6] for additional details. Transyt-7F was the computer program selected to illustrate the mobility impacts various improvements have. The program is a flexible signal optimization and evaluation program that is capable of modeling traffic networks with intersection traffic control ranging from stop signs to complex signal timing plans.

5.1 GENERAL ISSUES FOR CONSIDERATION

Location and orientation of grade-separated structures could be key issues when developing a strategic arterial. Users benefit when an intersection is grade separated, however, an analysis of the corridor may reveal that congestion is only moved to an intersection that is not able to handle the increased traffic or that improvements elsewhere on the corridor may provide the greatest benefits. The orientation of the structure specifies which through traffic has the advantage of not passing through signals. The orientation may need to favor a particular route to meet strategic arterial goals or may need to favor a route due to high through volumes.

Transyt-7F was used to determine the delay experienced by major road drivers for different grade-separation orientation. Drivers on the major road experience 12.0 veh-hr/hr of delay at an at-grade intersection. When the intersection is upgraded with a grade-separated structure, the major road drivers experience 9.0 veh-hr/hr of delay if the orientation of the structure favors the cross street traffic and 7.0 veh-hr/hr of delay (to the exiting traffic) if the structure favors the major road traffic. When the structure favors the cross street, all major road traffic is forced through signals whereas when the structure favors the major road, only the major road's turning vehicles travel through a signal.

Six conditions were analyzed to illustrate the effects that location and/or orientation of grade-separated structures have on travel speed and delay for a corridor. The analysis used corridors that ranged from having five at-grade intersections within a mile to having grade-separated structure at each of the five intersections. The four other conditions evaluated had either one or two grade-separated structures located within the corridor; in one condition the structure was oriented to favor the cross street traffic rather than the major road traffic. The presence of grade-separated structures did increase the speed along the major road, however, the speed was not constant throughout the length of the corridor. The speed for the through traffic on the major road increases prior to a grade-separated structure, and decreases significantly upon approaching the next signalized intersection.

Grade separating the most congested intersection along a corridor was also simulated. The improvement caused a decrease in the delay along the corridor, but the separation had only a minor impact on the average through speed from one end of the arterial to the other.

Transyt-7F was used to illustrate the effects of additional signals on average travel speed. Intuitively, the average travel speed should decrease with the increasing number of signalized intersections and the simulation runs support this concept. The runs also illustrated the magnitude of speed reduction that can be expected when signals are added. When the free flow speed of an arterial is assumed to be 45 mph, the average travel speed on the arterial ranged from 38 mph with signalized intersections spaced at 1.0 mile apart to 19 mph when signalized intersections are spaced 352 ft apart (similar to downtown conditions).

Other simulations illustrated that noticeable improvements in average travel speed can result from prohibiting left turns. The actual benefits realized from this type of improvement would depend on the cross street volume, possibility of U-turns on the cross street, and driver acceptance of accomplishing a left turn by making a series of turns that include a right turn and a U-turn.

The results from the simulation runs were conceptual in nature. For example, intersections are not evenly spaced with exactly the same volume of traffic at each intersection. The results do illustrate, however, that there are consequences in adding signalized intersections to a corridor. For each new signal installed, the flow and speed of the corridor traffic are affected. The analyses revealed that grade separations can impact the delay and speed on an arterial street. They allow commuters to go over (or under) stop-and-go conditions at an intersection, however, the average through speed along a corridor cannot increase substantially if signalized at-grade intersections are near.

A strategic arterial's primary function is traffic movement. Judicious use of turn prohibitions, signal spacing, and grade separations can improve traffic flow and, therefore, result in the high speeds and level of service associated with the strategic arterial classification. Since each arterial street is unique, different combinations of improvements must be examined to determine the optimal set of improvements that will provide the quality of service desired at an acceptable cost.

5.2 CASE STUDY

A case study was used to illustrate the impacts on an existing arterial facility (US 90A in Houston) that at-grade and grade-separation improvements have on mobility. Computer simulation runs were used to provide an understanding of the effect various improvement strategies have on arterial operations. Alternatives included examining relatively low-cost, easy to implement improvements, improvements planned by the Texas State Department of Highways and Public Transportation (SDHPT), and other strategies which improved the operations of US 90A.

The first Transyt-7F simulation (called Case I) used existing geometrics and traffic volumes (1986). The objective of this simulation was to determine if the program replicates existing conditions. The results from the Case I simulation were used as a basis of comparison to the do-nothing simulation (Case II). The do-nothing simulation used 1986 geometrics and 2000 year volumes projected by the State Department of Highways and Public Transportation to demonstrate the potential consequences of not implementing any improvements. Case II results were then used as a basis of comparison for the other six simulations that used different improvement strategies and 2000 year volume.

Table 7 presents the average through speed results from the Transyt-7F simulations. Average through speed is the measure of effectiveness that was primarily used during the evaluations and comparisons of the different cases. The computed speed on US 90A was also compared with the desirable operating speed range (45 to 55 mph, see Table 2-1) for a strategic arterial.

The Transyt-7F simulations indicate that the existing geometrics and operations (Case II) will be inadequate for the projected traffic volumes of the year 2000. It is highly unlikely that these poor operating conditions would ever actually be observed, the average commuter would not accept this level of service and would seek out an alternate route or mode of transportation. While the values may loose reasonableness when congestion reaches these extremes; the simulation results can be used for comparison purposes.

Table 7. Results from Transyt-7F runs.

Operational Conditions on US 90A	Average Through Speed (mph)
1986 VOLUMES **Case I** Existing Geometrics	39
2000 VOLUMES **Case II** Do-Nothing Alternative	12
Case III Intersection Spacing (Removal of two signals)	17
Case IV Prohibit Left Turns	10
Case V 8 Through Lanes	32
Case VI Extensive At-Grade Improvements	24
Case VII Proposed SDHPT Improvements	48
Case VIII Strategic Arterial	57

Several at-grade only improvements such as the removal of two signals to improve intersection spacing, prohibiting left turns, and adding through lanes, illustrate that the overall mobility of US 90A can be improved but to a speed that is still slightly below the 35 mph desired speed for a principal arterial street.

Schematics of anticipated improvements to US 90A were provided by the State Department of Highways and Public Transportation. These improvements included grade separations at each of the major intersections within the case study limits. The proposed grade separations produced dramatic results. The grade separations eliminated a large portion of the delay which produced a notable increase in the average through speed (48 mph).

The speed range for a strategic arterial is 45 to 55 mph. US 90A is within the desired speed range. However, delay at two at-grade intersections limits the speed on US 90A. At both intersections, the turning movements adversely impact the high volume through movements. These problems could be reduced if the grade separations at these two intersections were oriented to favor the through traffic on US 90A as was illustrated in the final simulation. Reorienting the grade separations would also remove all signalized control for the through movements on US 90A between IH 610 Loop and the county line. Delay would accrue to the cross street through traffic rather than on the heavier through traffic volumes on US 90A. While reorientation of the grade separations may not be possible due to right-of-way restrictions or other constraints, the simulation illustrated the benefits that the modifications could provide. Delay was reduced to a very small value and the speed increased from 48 mph to 57 mph when the grade separations are realigned. US 90A with these grade separations improvements would be in the strategic arterial class because it has high speeds and level of service, a strategic location in the city, grade separation of major intersections, and most importantly, it connects routes of similar or higher classification (e.g., IH 610 Loop to Beltway 8 and US 59 South).

CHAPTER 6

COST EFFECTIVENESS OF STRATEGIC ARTERIAL STREET IMPROVEMENTS

6.1 ESTIMATED COST OF A CONCEPTUAL STRATEGIC ARTERIAL SYSTEM

Ward [7] estimated the cost of a conceptual strategic arterial street system in Harris county. The costs represented the average principal element costs derived, with two exceptions, from a large number of urban projects completed by the State Department of Highways and Public Transportation since 1979. The principal elemental cost for a railroad overpass was derived from City of Houston records and the principal elemental cost for a roadway underpass was derived from Harris County Toll Road records. There is considerable variation in costs between projects, even similar projects can have subtle differences that would cause a significant disparity in the amount of monies spent to complete the work. Because these costs were from a variety of projects planned and constructed in differing environments, the average cost should produce credible results when applied to estimating the cost of a conceptual strategic arterial.

Right-of-way needs can vary substantially across the state and determining an average cost is difficult. For this analysis, right-of-way costs were estimated as 15 percent of the construction costs. In comparison, the right-of-way costs reported by the Greater Houston Chamber of Commerce in their 1989 Regional Mobility Plan as expended jointly by the State Department of Highways and Public Transportation District 12, Harris County, and the City of Houston, for the years 1982 through 1988, was about 16 percent of their respective highway and street construction expenditures.

When an expansion project for an existing facility is planned, the amount of items that are salvageable (e.g., storm sewers, utilities, traffic signal system) will influence the cost of the project. The average cost of rehabilitation (items salvageable) is about half of the cost for reconstruction (nothing salvageable). For this analysis, all projects were assumed to be reconstruction instead of rehabilitation. Table 8 lists the construction cost estimates for the principal elements of a conceptual strategic arterial street system.

Table 8. Estimated costs of principal elements in a conceptual strategic arterial street system.

Project	Cost	Average Project Length (mi)
Reconstruction	$ 500,000 per lane mile	NA
Roadway Overpass	$ 4,000,000 per unit	0.5
Roadway Underpass	$ 5,000,000 per unit	0.3
Railroad Overpass	$ 6,000,000 per unit	0.6
Railroad Underpass	$ 5,200,000 per unit	0.3
City Utility	$ 220,000 per mile	NA
Right-of-way	15 percent of construction costs	NA

Ward developed estimated costs for two conceptual strategic arterial street systems for Harris County. The first was for a minimum number of grade separations that are considered essential for the system to provide a minimum level of high quality service and reliability. Grade separations were provided when strategic arterials crossed each other and when strategic arterials crossed freeways. The number of grade separations in the second cost estimate was increased to supply a grade separation at an average system spacing of 2 miles. The 2-mile spacing of grade separations should result in signalized intersections every one to two miles. Both cases provided for grade separations at all railroad crossing. The number of overpasses and underpasses was estimated based on the assumption that environmental considerations will influence designs.

Table 9 lists the system cost for the 2-mile grade separation spacing. The strategic arterial street system is assumed to be 490 miles long and composed of only 6-lane facilities. Over and underpasses account for 150 miles in the system. Rehabilitation costs are used to estimate the 340 mile difference (490 miles - 150 miles) between the total system length and the lengths that are included in the interchanges. The system was also assumed to have three high-cost bridges.

Table 9. **Cost estimate of conceptual strategic arterial street system.**

Item	Quantity	Unit Cost	Total (1,000,000)
6-Lane Roadway	2040 lane miles	$ 500,000	$ 1,020.0
Utility Costs	340 miles	$ 220,000	$ 74.8
RR Overpass	50	$ 6,000,000	$ 300.0
RR Underpass	23	$ 5,200,000	$ 119.6
Street Overpass	185	$ 4,000,000	$ 740.0
Street Underpass	55	$ 5,400,000	$ 297.0
High-Cost Bridges	1	$10,000,000	$ 10.0
High-Cost Bridges	2	$50,000,000	$ 100.0
Construction cost, subtotal (rounded):			$ 2,600.0
Right-of-way at 15 percent of estimated construction cost:			$ 400.0
Total:			$ 3,000.0
Average cost per mile:			$ 6.1

6.2 COST EFFECTIVENESS

The Highway Economic and Evaluation Model (HEEM) can calculate a benefit/cost ratio and a measure of mobility (average speed) for proposed highway improvements. It was used to estimate the cost effectiveness of a typical 10-mile segment of a conceptual strategic arterial street system. The following analysis uses speed-capacity curve values developed by Ward [7] for strategic arterials instead of the values currently contained in the HEEM-II.

The user's costs calculated by the HEEM-II are time costs, operating or vehicular costs, and safety (accident) costs. Cost-related input factors are percent trucks, value of time for cars ($0.17/min), value of time for trucks ($0.32/min), discount rate (4 percent assumed), inflation rate (0 percent assumed), urban diversion speed (14 mph), current and future traffic costs, construction costs and year of construction, maintenance costs, and accident costs. The output of a HEEM problem typically shows that the reduction in time costs accounts for about 75 to 80 percent of the benefits, followed by operational and safety benefits. The HEEM compares the discounted costs generated by one alternative with those of another alternative. The difference between the costs represents the user's benefits. The benefits are then divided by the net cost (investment and maintenance cost of one alternative less that of the other) to give the benefit/cost ratio. The HEEM calculates the user's costs based on the traffic projections that are provided in the input data. The model does have a default diversion of traffic if an alternative is subjected to too much traffic.

Table 10 shows the results of the HEEM runs that provided the benefit/cost ratios and the average travel speeds from improving a 10-mile segment of a 4-lane city street to a 6-lane city street or to a 6-lane strategic arterial with a signalized intersection every 2 miles. The traffic volumes for both alternatives were assumed as 30,000 ADT for 1990, 45,000 ADT by 2000, and 60,000 ADT by 2010. The construction cost for a 6-lane city street improvement was estimated as $3 million per mile. The results from the model demonstrate that the higher quality facility, even though more expensive, is a better investment.

Table 10. Cost-effectiveness analysis.

Existing Facility	Proposed Facility	Construction Costs ($ 10^6)	Present Value of Benefits ($ 10^6)	Benefit/ Cost Ratio	Average Speed (mph)	
					Do Nothing	Construct Facility
Urban 4-Lane City Street	Urban 6-Lane City Street	3.0	275.5	9.2	18.8	21.2
Urban 4-Lane City Street	6-Lane Strategic Arterial	6.1	729.6	12.0	18.8	41.5

CHAPTER 7

TEXAS STATE ROLE

Many of the basic philosophies concerning means of providing continuity and assuring defined levels of quantity and quality of traffic service that have been applied successfully to freeways can be transferred to strategic arterials, but with due consideration of the particular environment in which strategic arterials are likely to exist. Decisions to build freeways are not made by scrutinizing every design element and subjecting it to individual economic analysis, rather these decisions are based on broad analysis of service to be provided by the freeway facility, with basic design standards being relatively rigid. Furthermore, continuing efforts such as incident management and metering of entrance-ramp traffic are made to maintain and enhance the traffic carrying capabilities and reliability of freeways--practices not normally found on arterial streets. To accomplish a similar, but subordinate, role for strategic arterials, strategic arterials need to be designated by policy and then supported by design guidelines, regulations, and appropriate legislation.

The goals of strategic arterials will need to be attained by the adoption of a policy designating specific facilities as strategic arterials and enacting the necessary regulations to ensure the appropriate and continuous application of design standards. Designation of a specific facility in this way is aimed at ensuring the consistent application of guidelines to ensure that the facility will be able to provide the envisaged levels of mobility. Establishing strategic arterial status is deemed necessary to reduce the adverse effect which access request often have on efforts to maintain high level of service on urban streets. With such designation, clear communication will be directed to all involved including elected officials, public-participation groups, and road users; thus fostering understanding of required standards and goals for strategic arterials. Another aim of designating a strategic arterial is to obtain approval of the principles to be used for locating a given class of road, with design standards implicit in the designation, rather then considering each element separately. This is analogous to practices that are already associated with freeway planning and development.

The areas where regulations and clear understanding are needed include the general acceptance of:

- the principal of some preferential treatments to strategic arterials, in the control of access and the allocation of signal green time
- the use of grade separations at some urban street intersections
- implicit power to the transportation authority to restrict new driveways, where alternative access exists
- the requirement of a driveway permit for all new access points and where changes in land use occur in order to secure high standard driveway designs
- authority to undertake construction work on existing driveways so that they conform to the selected standards
- authority to implement incident response, including authority to remove accident vehicles from roadway.

Designating a strategic arterial and supporting the designation by strict regulation may in practice prove to be one of the most important elements in determining the success or failure of a project.

Implementation of strategic arterials will be subjected to local requirements, which will play a major role in the successful implementation of a strategic arterial network. The state highway authorities are best suited to play the role of controlling the development of a strategic arterial system. Community response to the implementation of strategic arterials can be expected to come from different sources, and be different in content. The dissemination of information to the community and public participation play important roles in the acceptance, or rejection of highway projects of the types under consideration. There are also additional strategies to handle community response, such as through emphasizing the safety aspects of proposed improvements.

For strategic arterials to be successful and distinguishable from other classes of streets, design guidelines will need to be conscientiously interpreted and appropriately applied. To reach this ideal, the responsible highway agency representatives will need to pursue the strategic arterial concept with great vigor and determination. The process will need political and administrative backing from the highest levels possible and will require additional efforts to generate the level of community support needed for successful implementation.

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