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16. Abstract

Urban mobility is becoming an increasingly greater concern in major Texas cities. To address this problem, a variety of actions will need to be taken. Some will be oriented at reducing the demand for transportation, others at increasing the supply of transportation services. One of the supply options involves the possibility of developing a system of regional arterial streets, or super streets. The arterial street system in Texas is underdeveloped and, as a result, too much traffic is forced onto the freeways. Upgrading the arterial street system appears to represent a feasible and cost effective approach for enhancing urban mobility. This report documents the role currently being served by arterial streets in Texas and speculates on what that role could be if the arterial system were significantly improved.

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Form DOT F 1700.7 (8-69)

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
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yd²	square yards	0.836	metres squared	m²
mi²	square miles	2.59	kilometres squared	km²
ac	acres	0.395	hectares	ha
	MASS (weight)			
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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
ft³	cubic feet	0.0328	metres cubed	m³
yd³	cubic yards	0.0765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

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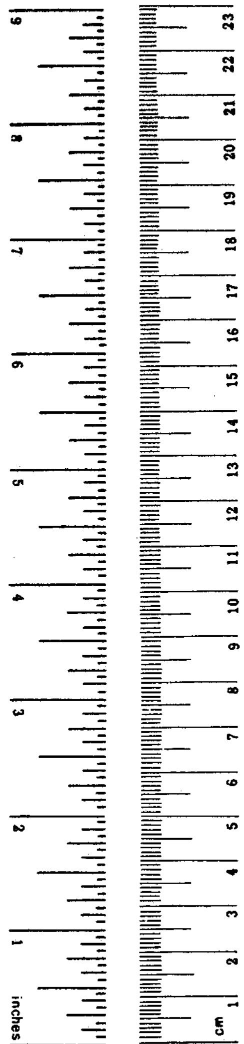

APPROXIMATE CONVERSIONS TO SI UNITS

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m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
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m²	metres squared	10.764	square feet	ft²
km²	kilometres squared	0.39	square miles	mi²
ha	hectores (10 000 m²)	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
m³	metres cubed	35.315	cubic feet	ft³
m³	metres cubed	1.308	cubic yards	yd³

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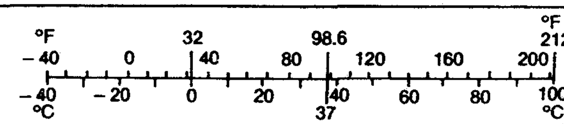


These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

AN ENHANCED ROLE FOR THE ARTERIAL STREET SYSTEM IN TEXAS CITIES

Research Report 1107-1

The Role of the Arterial Street System in Urban Mobility

Research Study 2/3-8/10-88-1107

Sponsored by

Texas State Department of Highways and Public Transportation

in Cooperation with the

U.S. Department of Transportation

Federal Highway Administration

Texas Transportation Institute

The Texas A&M University System

Center for Transportation Research

University of Texas

November 1988

ABSTRACT

Urban mobility is becoming an increasingly greater concern in major Texas cities. To address this problem, a variety of actions will need to be taken. Some will be oriented at reducing the demand for transportation, others at improving the operation of the system, and still others at increasing the supply of transportation services. One of the supply options involves the possibility of developing a system of regional arterial streets, or super streets. The arterial street system in Texas is underdeveloped and, as a result, too much traffic is forced onto the freeways. Upgrading the arterial street system appears to represent a feasible and cost effective approach for enhancing urban mobility. This report documents the role currently being served by arterial streets in Texas and speculates on what that role could be if the arterial system were significantly improved.

Key Words: Arterial Streets, Functional Classification, Mobility, Urban Transportation

SUMMARY

Data clearly indicate that major Texas cities are experiencing undesirable levels of congestion, and that congestion is continuing to worsen. While actions to reduce demand for transportation must be pursued, to also address this problem from the supply side, it is apparent that a need exists to: 1) develop and expand the urban freeway system; 2) implement effective mass transportation systems; and 3) develop and expand the regional arterial street system.

At present, an at least adequate level of dedicated funding exists to undertake the freeway and transit improvements. The funding available for development and expansion of the arterial street system is not generally from a dedicated funding source.

This report attempts to define the current role of the arterial street system in Texas and to speculate on what that role could be if an effective system of arterial streets were developed in the major urban areas. It appears that the arterial street system in Texas is significantly underdeveloped, and that expansion of this system can result in a highly cost effective approach for alleviating urban congestion.

The following information summarizes the major points developed in this report.

1. The Central Business District (CBD) is no longer the major destination or origin of peak-hour trips.

Major activity centers located in areas other than the CBD have become the source of a large share (68 to 91 percent) of new office construction. These major activity centers resemble "mini" CBD's, with the major difference being that there may be a number of the activity centers scattered out over the total urban area; each of these suburban centers is not served by a system of radial freeways. It is envisioned that the trend of developing major activity centers outside the CBD will continue in the future.

2. The development of transit systems alone will not solve the urban congestion problem.

Transit systems in Texas primarily serve a relatively small portion of the population. Many users of these systems either do not have an auto available or are physically unable to drive. Transit can also be attractive to those commuters who have access to high quality express service for their trip to a major activity center. However, the high proportion of automobile ownership and the desirability of private mobility ensure the role of the automobile as the preferred mode of surface transportation in the foreseeable future.

3. Freeway mileage can not grow substantially in a short period of time.

Freeway systems have been on the planning agenda in Texas for a long period of time. These systems are now nearing completion in the major urban areas, and the principal freeway improvement program is one of rehabilitating the older freeways with the addition of freeway capacity wherever feasible.

Building new freeway systems within developed urban areas is a difficult and time consuming problem. Institutional opposition, increasing cost of right-of-way, construction and regulatory restraints, and traffic congestion have all contributed to increasing both the time and cost needed

to plan, design, and build freeways. It is not uncommon to find that it may take 15 or more years to take a freeway project from initial planning through construction. This long time period greatly increases the uncertainty associated with ultimate project completion.

4. The volume and percentage of total traffic served by freeways in Texas is greater than in other states.

In a special study of mobility in Texas, vehicular travel on the freeways and principal arterials of seven large urban areas in Texas and 22 other United States cities was studied. It was found that freeways and principal arterials handled approximately 60 percent of the daily vehicle-miles of travel (VMT) in urban areas both outside and within Texas. It was also found that, in the five most congested Texas cities, 41 percent of the daily VMT occurs on freeways, and only 18 percent is on the principal arterials. The averages of the cities outside Texas, however, indicate that 34 percent of the daily VMT is on the freeways, and 26 percent is on the principal arterials. An implication is that arterial streets in Texas, if properly developed, can be expected to serve higher trip volumes and, by so doing, reduce demands on the freeway system.

5. The principal arterial street system in major Texas cities in general is not continuous and does not have adequate capacity for significant distances.

While features other than continuity are certainly important in attracting trips to arterial streets, it is apparent that, without reasonable continuity, there is a limit to the volume of trips that will divert from freeways to arterials. The arterial streets in Texas tend to lack continuity. In this study, for an arterial to be considered "continuous", it had to have a cross section of at least four lanes over a distance of at least four miles. Roadway inventory data suggest that 85 percent of the arterial lane-miles in Dallas, 60 percent of the lane-miles in Houston, and 35 percent of the lane-miles in Fort Worth conform to this definition of continuous.

A case study was conducted to compare two Texas corridors, one in the north Dallas area with a relatively good arterial street system and one in west Houston with a relatively poor arterial street system. The arterials in north Dallas served 30 percent more of the VMT than was served by arterials in west Houston. While continuity may not be the only reason for the difference, it certainly appears to be a contributing factor.

It seems reasonable that the arterial streets in Texas, if properly developed, could serve 25 to 35 percent more of the VMT than is presently served by those streets. This finding substantiates the conclusion that the freeways in Texas have been relied upon to carry an unduly large portion of the travel load. The major transportation improvement programs historically have focused on the freeways with less funding for arterial streets.

6. It seems desirable and feasible to increase the ability of the principal arterial system in major Texas cities to carry a larger share of the daily travel.

The first five findings presented above all point to the desirability of upgrading the principal arterial system in major Texas cities to carry a larger share of the daily VMT. The major question to be answered concerns the feasibility of substantially improving the arterial street system. The answer will require intensive study. It is probable that both improved operations of the existing arterial system as well as construction of new capacity will be needed.

It seems likely that, to provide the capacity increases that will be required, it will be necessary to implement a substantial mileage of the Super Arterial. In this study, Super Arterials are generally considered to be a system of regionwide arterial streets that are developed to high design standards to strongly emphasize the traffic movement function of the arterial street. To accomplish this mission will no doubt require the acquisition of a significant amount of right-of-way and the establishment of access control; some public resistance to these plans should be anticipated. A substantial and predictable source of funds will be necessary to facilitate the development of such a system of regional arterial super streets.

Thus, the feasibility of implementing such an arterial street system will require considerable study to provide a good assessment of this problem.

IMPLEMENTATION STATEMENT

Agencies at all levels of government are aggressively pursuing plans to develop a transportation system that will provide acceptable levels of urban mobility. In doing this, increasing attention is being given to arterial street improvements. The state has recently expanded its role in this area, and transit authorities are also becoming more involved in street improvements.

This report is intended to help those implementing agencies to better understand the extent of the role currently being served by arterials streets and to identify what that role might be. Approaches that can be used in upgrading the arterial street system are also presented.

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. This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

I. INTRODUCTION

The achievement of acceptable urban mobility is a prime goal for Texas, but one which is proving difficult to realize in the major urban areas of the state. The State Department of Highways and Public Transportation (SDHPT) has placed major emphasis on the development of a freeway system in these urban areas, but these facilities alone have not been enough to cope with peak-period traffic and the ever increasing demands for urban mobility. Similarly, the creation of transit authorities funded with dedicated sales tax revenues will not, by itself, bring about uncongested urban travel.

As a consequence, it seems desirable to closely study the potential role of the arterial street system in providing urban mobility; that is the purpose of this report. Consideration is given to the trends in urban development, the impact of these trends on the street network (Figure 1), and the possible techniques that can be utilized to improve operations along the arterial street system in order to help cope with the ever increasing volumes of traffic.

The major objectives of this report are as follows:

1. To overview the trends in urban development in the major metropolitan areas of the state;
2. To determine the impact of these trends upon the existing network of streets and freeways;
3. To identify the present role of the arterial street in Texas cities and to speculate on what that role could be; and
4. To present desirable characteristics of a functional street system and to describe possible techniques that could be utilized on the arterial street system to improve traffic operations and capacity in order to serve a more significant role in improving urban mobility.

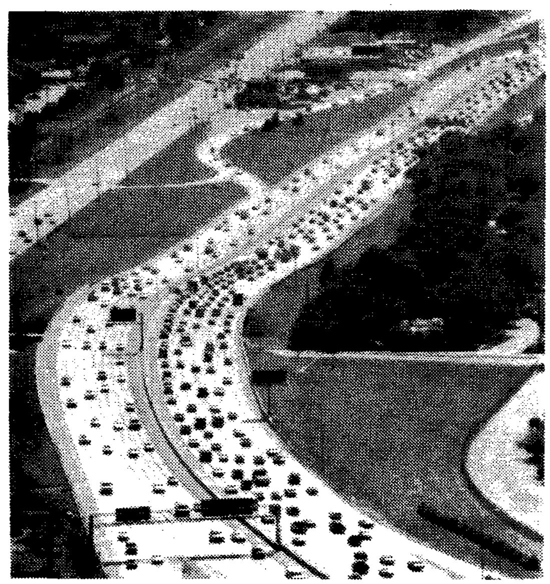


Figure 1. Typical Peak-Period Operation, Texas Freeway

Congestion in large Texas cities has been increasing in recent years at an average rate of 3 percent per year. In addressing this problem, increasing attention should be given to the potential role of the arterial street system.

II. THE ARTERIAL STREET SYSTEM AND URBAN MOBILITY

Since the advent of the automobile in the 1920's, and particularly since the 1940's, major cities in the United States have spread and expanded into a conglomeration of suburban, interdependent, somewhat randomly-spaced major activity centers. These activity centers furnish jobs, services, shopping, and entertainment for a population whose preferred lifestyle centers on living in single-family, detached housing and commuting to these activity centers in their own vehicles. This condition is not confined to the larger urban areas; it is also evident in many smaller cities, where "downtown" is characterized by vacant store buildings, and where most commercial activities have moved to shopping centers in the outskirts. Because of this pattern of growth, traffic congestion, once believed to be a special affliction confined to the inner city, has rapidly spread to the suburbs.

Emerging Trends In Urban Development

Transportation planners have been slow to acknowledge this more recent phenomenon, having traditionally focused their attention on improving mobility to the central business district (CBD), as it was considered to be the hub of business and cultural activity (Figure 2). What has developed is that, in many urban areas, suburban freeways and the supporting street network now suffer more intense and prolonged traffic congestion than that experienced on the radial freeways serving the CBD. In Dallas and Houston, the highest traffic volumes are recorded on the circumferential freeway facilities in the vicinity of the Galleria suburban centers.

Much of our planning has not anticipated or even tracked this recent style of growth. The supply of roads and streets needed to accommodate trip demands has expanded at a much slower rate than the trip demands generated by the multiplicity of activity centers (Figure 3). Increasing the supply of road and street services to these centers is one of the most difficult and frustrating problems confronting government in the larger urbanized areas.

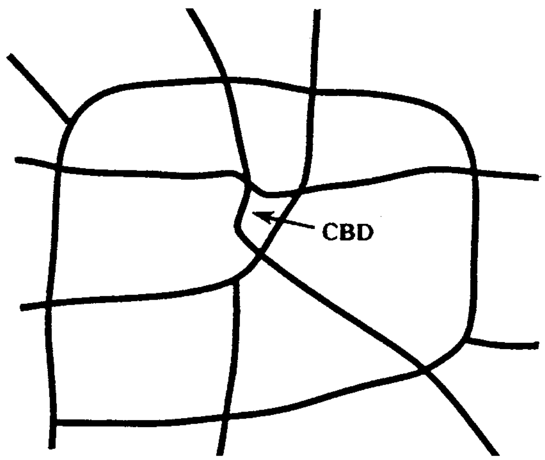


Figure 2. Typical Texas Radial-Circumferential Freeway System

Our major transportation facilities were developed primarily to serve travel to the downtown area. While this is still a concern in Texas cities, downtown-oriented travel is no longer the major part of urban commuting.

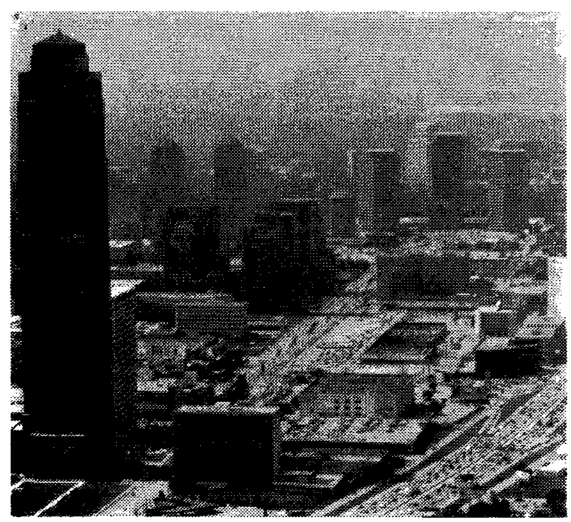


Figure 3. City Post Oak/Uptown Development, Houston

Development trends in Texas have changed travel patterns. The development of major suburban centers has caused suburban to suburban travel to become the primary component of urban commuting.

The growth of the suburban major activity center can be attributed to several factors: 1) relatively low land prices, as compared to those in the CBD; 2) availability of large tracts of land; 3) proximity to single-family housing; 4) easy access to major road facilities; and 5) at least initially, the perception or hope that traffic conditions would be better than those near the CBD. This sort of commuting lifestyle requires space and can, with an adequate road and street network, involve weekday vehicle one-way work trips of only 20 to 25 minutes. These work trips, typically about 10 miles in length, are usually perceived as tolerable. The strong appeal of this type of urban land use is evident when examining office construction figures. Major activity centers have become the source of a large share of new office space construction in some cities, outspacing the volume of new office construction in the CBD. In 1982 in Atlanta, Boston, Denver and Houston, between 68 and 91 percent of all new office space added was outside the CBD (1). The activity centers developing in Texas are large, employing more persons than are employed in many major downtown areas (Table 1).

These major activity centers resemble "mini" downtowns with a major difference being that, while there is only one CBD, there may be many major activity centers. The CBD also evolved over decades, which allowed its impact on the city's environment to be absorbed gradually, whereas modern major suburban shopping and office centers developed more quickly, often in 3 to 10 years. The development of major activity centers (Figure 4) outside the CBD will undoubtedly continue as the country moves from an industrial-based to a service-oriented economy and as communications become more refined and

Table 1. Approximate Size of Selected Major Activity Centers

Activity Center and Location	Estimated Daytime Employment	Sq. Ft. of Office Space (millions)
Selected Downtown Areas		
Baltimore	---	7.8
Cleveland	50,000	16.9
Miami	65,000	8.0
Houston	150,000	34.1
Dallas	117,000	25.6
Selected Houston Activity Centers		
Post Oak/Galleria	65,000	23.3
Greenway Plaza	48,000	9.7
Texas Medical Center	46,000	---
Selected Dallas Activity Centers		
Galleria/LBJ	27,000	---
Las Colinas	32,000	---

Source: Reference 2, Houston Metropolitan Transit Authority and North Central Texas Council of Governments.

Major suburban activity centers in large Texas cities employ literally tens of thousands of workers. Comparatively, they represent very significant developments.

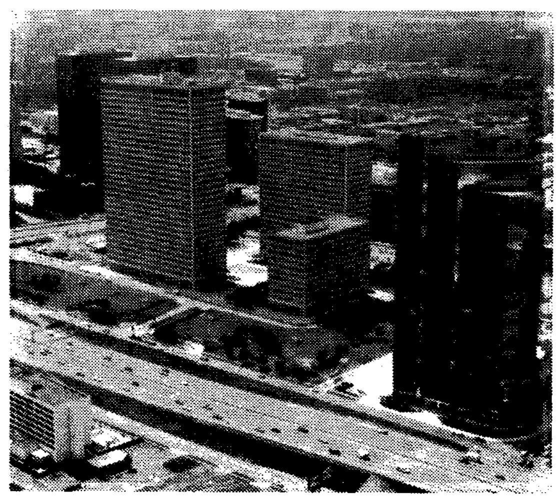


Figure 4. Greenway Plaza Development, Houston

The large suburban activity centers developing in Texas are larger than the downtown areas of many major cities.

the perceived need for "hands on" management and negotiation diminishes.

The Urban Freeway System

The backbone of the urban transportation infrastructure in Texas is the freeway system (Figure 5). These freeways accommodate vehicle trips once carried by arterial streets and have been very effective in diverting traffic away from the arterial street network. Within the overall highway system, nearly all the freeway links have been completed. The few additional candidate links to this system of freeways, which for the most part were planned during the 1950's and early 1960's, are generally located around the periphery of the urban areas and may be expected to enhance mobility in future growth areas rather than provide

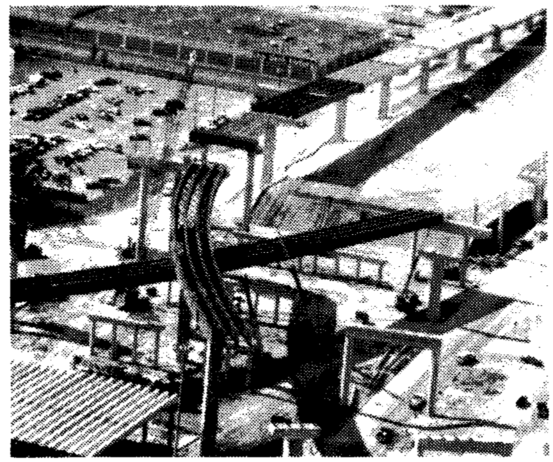


Figure 5. Urban Freeway Construction, Houston

While our existing freeway system is, to the extent feasible, being reconstructed with greater capacity, these actions alone are not adequate to accommodate growing travel demands. New freeways are generally not feasible in heavily developed and congested parts of the urban area.

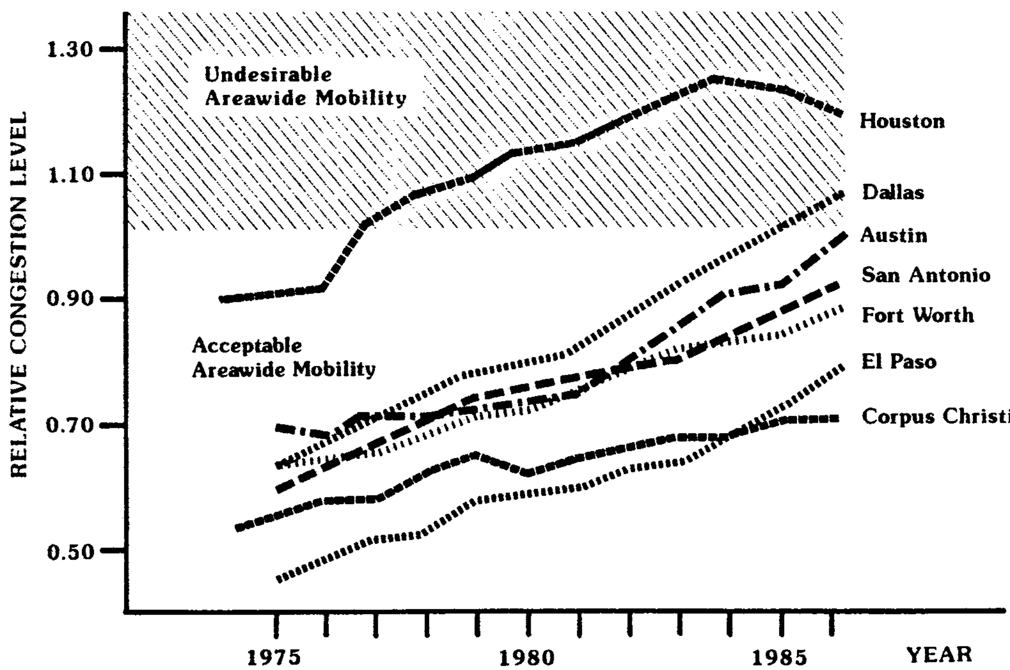


Figure 6. Relative Congestion Levels in Major Texas Cities, 1975-1984

Congestion continues to increase in all the large Texas cities. Undesirable areawide congestion already exists in Houston and Dallas. Surveys consistently show that traffic congestion is perceived as being one of the top 2 or 3 concerns of urban Texans.

congestion relief within the developed urban areas. Currently the principal freeway improvement program is to rehabilitate the older freeways and add capacity wherever feasible and affordable.

Building new freeways or even widening existing freeways, within developed urban areas increasingly appears to be infeasible as the sole solution to the traffic congestion problem. The very success of the freeway system has spawned such intensive land use that it inhibits the extension of freeway services into new areas.

Institutional opposition, increasing costs of construction, right-of-way and regulatory restraints and traffic congestion have all contributed to increasing both the time and cost needed to plan, design and build freeways. It is not uncommon for a freeway to take 15 or more years for completion, from initial planning through construction. This long time cycle from concept to completion, which may exceed political careers and may promise uncertain benefits for middle-aged and older taxpayers, makes generating and maintaining enthusiasm for freeway projects difficult. The most feasible and promising locations for new freeways on new locations will be in the developing areas along and adjacent to the fringes of growing urban areas where large tracts of land are available, where fewer people and businesses need to be relocated, and where there are fewer governmental entities involved in the planning and approval process. Otherwise, within developed urban areas, building new freeways on new locations will largely depend on the opportunity or chance of finding corridors where controversy or neighborhood impact is likely to be minimal.

The diminished growth of freeway mileage is coupled with the continued increase in daily vehicle miles travelled (VMT) on the freeway network. A method of measuring congestion levels in urban areas has been developed (3, 4) that shows the already severe network-wide congestion in Houston, and points out that Dallas, San Antonio, and Austin are fast approaching similar levels (Figure 6). In comparison to other southern, southwestern and western cities, it is also apparent that our large Texas cities have become relatively congested (Table 2).

The cost of congestion is also substantial. It is estimated that, in 1986, the cost of this congestion in the 7 largest Texas cities exceeded $4 billion (Table 3). The cost in Houston alone was $1.9 billion, and in Dallas was $1.1 billion; all these costs continue to increase.

Table 2. Relative Congestion Levels In Selected Major U.S. Cities

City	Congestion Index[1]	Urban Area Density (Persons/ Sq. Mi.)	Daily Vehicle Miles Per Capita[2]
Los Angeles	1.32	5110	13.7
San Francisco-Oakland	1.24	4230	13.5
HOUSTON	1.21	1600	12.5
Phoenix	1.18	1970	12.3
Atlanta	1.15	1210	16.5
Miami	1.10	4080	10.8
Seattle	1.09	2235	15.2
DALLAS	1.05	1345	16.2
Denver	1.01	1735	13.5
San Diego	1.00	2940	14.4
AUSTIN	0.98	1400	16.0
Portland	0.97	2600	9.1
Tampa	0.96	1465	11.0
St. Louis	0.95	2565	13.7
Minneapolis	0.93	2165	10.1
SAN ANTONIO	0.91	2140	13.5
Milwaukee	0.91	2200	9.7
Sacramento	0.90	2825	12.6
Nashville	0.89	1170	16.4
FORT WORTH	0.87	1350	13.4

[1]This normalized relationship is based on VMT? Lane mile ratios for freeways and principal arterial streets. A congestion index in excess of 1.0 indicates that area wide urban mobility is undesirable.

[2]Sum of daily VMT for principal arterials and freeways.

Source: Reference 5.

While congestion in Texas cities is not as severe as that presently occurring in some parts of the country, congestion levels are, nevertheless, undesirably high.

Table 3. Estimated Cost of Congestion In Large Texas Cities, 1986

City	Annual Cost of Congestion (Millions of dollars)
Houston	$1,895
Dallas	$1,120
Fort Worth	$ 420
San Antonio	$ 305
Austin	$ 275
El Paso	$ 55
Corpus Christi	$ 20
TOTAL	$4,090

Source: Reference 5.

The annual per capita cost of congestion in Houston is approximately $700.

Alternatives to Single-Occupant Vehicle Commuting

Increased investment in public transit, the application of transportation systems management (TSM) techniques, and demand management are often proposed as compelling solutions to the congestion problem. While these actions are a part of the solution to mobility problems, they are not sufficient, by themselves, to fully address these problems.

Public transit (Figure 7) has been espoused as a vigorous competitor to, and a substitute for, the automobile, and in some cities this may be the case. Cities that developed a form and lifestyle dependent on transit well before the age of the automobile have transit systems that satisfy a substantial portion of the demand for transportation services. On the other hand, cities that grew up with the automobile have been less influenced by transit. Subsequent attempts to use transit as a viable alternative to the automobile have proven to be effective in older cities having high population densities. However, in younger cities (particularly those in the western and southern United States) with lower and more dispersed population densities, transit has served primarily the relatively small segment of society that can't afford private transportation, or those who can afford a private means of transportation but prefer, at least for the work trip, to use public transportation. In Texas cities, in some corridors, transit will be a part of the solution to urban traffic problems, but certainly not the entire solution.

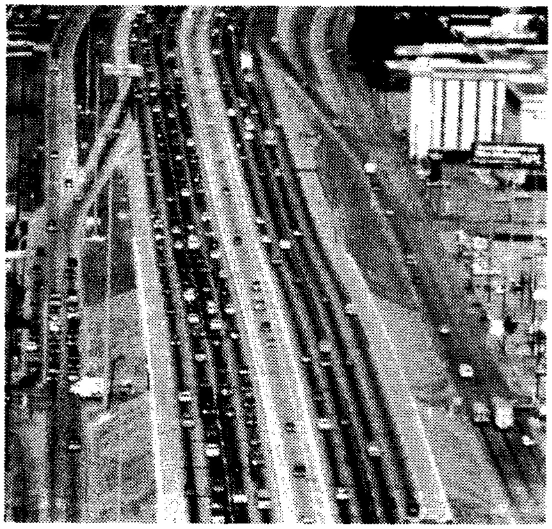


Figure 7. Houston Transitway

Innovative transit techniques, such as the freeway transitways being built in Houston, can help serve some peak-period traffic in congested corridors. However, the private auto will continue to serve over 90 percent of daily urban person trips.

Studies suggest that the high proportion of automobile ownership by virtually all segments of society and the conveniences of private mobility (even with the congested driving conditions encountered during the rush hours) ensure the automobile's role as the preferred mode of surface transportation in the foreseeable future, with transit playing a secondary role (6, 7). It is estimated that the investment in automobiles in the United States is nearly one trillion dollars, and it is unlikely that such an investment will be abandoned, or that the demand for adequate street facilities will diminish soon. It would be unwise to plan for, or even expect, meaningful relief from traffic congestion because of any significant future changes in lifestyle, land use, or modal choice of transportation.

Transportation systems management (TSM) techniques (Figure 8) are another means of improving traffic operations.

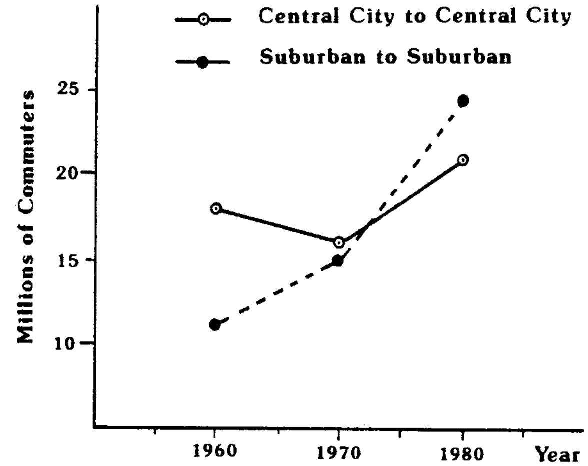
Figure 8. Concrete Barriers Used to Control Arterial Street Access

TSM improvements, such as the use of concrete barriers to control access, can be extremely cost effective. However, since they generally result in relatively minor increases in capacity, these improvements alone are not capable of addressing urban congestion issues.

Propelled by the oil embargo of 1973, TSM techniques became popular and included programs to modify both the demand and supply sides of transportation. Ridesharing programs, promoting the formation of carpools and vanpools, were initiated. Employers were encouraged to provide flexible work hours to reduce the morning and afternoon peak travel periods. Even electronic paycheck transfers were created to reduce employee trips to banks in order to alleviate downtown congestion. Signal progression, parking restrictions, and lane restriping were all supply-side efforts to improve the flow of traffic in the network. TSM techniques are still being applied successfully but have a relatively limited and local effect in improving areawide mobility, even though they are generally cost-effective.

Urban Commuter Travel Patterns

That suburbia is booming and metropolitan commuting patterns are changing is confirmed by the recent report, "Commuting in America" (8). This report describes the predominant commuter flow pattern in the larger metropolitan areas as suburb-to-suburb. Although the traditional pattern of commuting between the suburb and the central city is still growing, it is no longer the dominant pattern but ranks third, behind suburb-to-suburb and central-city-to-central-city trips. The major report findings, primarily derived from census data, are that: the majority of work-trip growth (58 percent) occurred in the suburb-to-suburb commuting; suburb-to-central-city commuting accounted for 25 percent of the growth; and central-city based trips (those going to the suburbs and those destined to other parts of the central city) each accounted for about 9 percent of the total growth in commuting between 1960 and 1980. Figure 9 compares central-city-to-central-city to suburb-to-suburb commuter trips between 1960 and 1980 and shows the change in metropolitan trip patterns. The commuting trip is defined as the home-to work trip and the work-to-home trip, and accounts for most of the peak-period traffic demand. The tolerable accommodation of this commuting trip is a critical objective for the suppliers of both public highways and public transit.



Source: Reference 8.

Figure 9. Central City and Suburban Commuting Trends, USA, 1960 to 1980

Since 1960, suburban-to-suburban commuting has increased substantially and now exceeds central city to central city commuting.

The report (8) suggests that, not only have the commuting patterns changed, the intensity of suburban commuter traffic has increased faster than population growth because the proportion of people who work has increased. Due partly to more women entering the labor force, jobs have tended to be located in the suburbs, and the use of private vehicles as the means of travel to work has increased. This condition has also been amplified by such factors as a decrease in the use of public transit, walk-to-work trips, and work at home. These last factors may well be considered as effects rather than causes of increases in suburban travel, due to the difficulty of supplying public transit to a diffused suburbia with a general increase in affluence.

The analysis of commuting patterns brings focus to some serious implications for the future of our transportation facilities. The character of commuting has been changing. It will likely continue to do so for the remainder of this century and will have a substantial impact on the existing transport system. Some things to be considered are the following.

1. What the effect will be of the growth in auto commuting and the adequacy of transportation plans based on population growth as a principal determinant of future travel demand.

2. The new trip patterns, which have occurred on a road system with inadequate capacity which is more oriented to radial patterns than circumferential flow, have seriously strained metropolitan infrastructure.

3. The competition for available road space in metropolitan areas, in the absence of local facilities, has so overloaded the freeway systems that these facilities are not performing their mission of accommodating long-distance traffic. The present competition between the needs of the local commuter and the needs of long-distance traffic on the same limited road space will be a critical concern in the future.

4. Opportunities for public transit to make substantial contributions to commuting needs outside the markets it currently serves will be limited in the future by available technology and institutions. The suburb-to-suburb market will represent a very difficult and a very expensive market to serve for traditional forms of transit.

5. The potential for greater "community balance" between workers and jobs in suburban areas exists, with promise for more efficient commuting patterns and other far-reaching benefits. This suggests that new requirements for interaction and cooperation between metropolitan jurisdictions will arise.

III. A ROLE FOR THE ARTERIAL STREET SYSTEM IN TEXAS

The intent of this section is to identify the role currently being served by arterial streets in Texas and to speculate on what that role could be. A description of the extent, usage and continuity of the arterial system is presented as is a brief summary of the magnitude of expenditures associated with constructing and maintaining that system.

Arterial Street Network Improvements

Considering the problems presented, it is logical to ask the question regarding what should be done. A strategic thoroughfare network is a possibility, providing an attractive and seemingly neglected approach to coping with urban congestion problems. It involves supplementing the freeway system with better arterial streets. The freeway system is carrying a disproportionate amount of the VMT in urban areas. It is believed that a significant amount of these VMT, which end up on the freeway system, can be diverted to a network of thoroughfares designed to intercept and accommodate intermediate trip demands of 2 to 5 miles in length. Such thoroughfares, in order to be effective, should be constructed to appropriately high geometric design standards, provide a uniform quality of facilities and access control along continuous routes of at least 4 miles or more in length, and utilize grade separations at critical intersections. The effectiveness of arterial streets in diverting freeway traffic will depend on the characteristics of the street and freeway network, land use, geometric features, arterial length, accessibility to abutting property, and regional trip length characteristics. A strategic arterial network could also benefit cross-town bus transit operations because of the length, continuity, and improved traffic flow characteristics of such a system.

Improving an arterial street per se is not innovative, but implementing a program whereby a regionwide network of selected arterial streets (Figure 10) improved for the purpose of enhancing regional mobility would be innovative. Additionally, for the reasons given previously, the provision of a high-quality strategic arterial network may be the only practicable means of extending high-quality traffic services to future growth areas.

Figure 10. Grade-Separated Arterial Street Intersection

Improving an arterial street per se is not innovative, but implementing a regionwide system of super arterial streets would be innovative.

The remainder of this section presents comparisons of the roadway networks in Texas and other U.S. cities to examine the potential for handling existing and future traffic on the major urban streets and freeways in Texas. A case study involving sections of Texas cities which have developed with different roadway patterns is presented as an illustration of the potential for arterial street systems and the relief that might be provided to the urban freeway systems through development of an improved arterial street system. Funds available for city street construction and maintenance are compared to those available for freeways and transit systems.

Characteristics of the Arterial Street System in Major Texas and Other U.S. Cities

Table 4 illustrates summary data for the freeway and principal arterial street systems in seven large Texas and 22 other U.S. cities (5). Daily vehicle-miles of travel (DVMT) on the freeways and principal arterials provide an estimate of the amount of emphasis placed on each functional class by the planning and funding agencies associated with an urban area. Freeways and principal arterials handle approximately 60 percent of the daily vehicle miles of travel in urban areas outside and within Texas. The five most congested Texas cities average 41 percent of the daily VMT on freeways and 18 percent on principal arterials. The average of the cities outside Texas however, indicates 34 percent of this VMT occurs on the freeways and 26 percent on the principal arterials. An obvious implication is that, due to an inadequate arterial system, Texas cities are attempting to serve too much travel and have become too dependent on the freeway system.

The average total VMT for cities outside Texas and the five most congested Texas cities are approximately equal (35,070,000 versus 34,870,000), indicating that the cities might have similar transportation facilities (Table 4). Within these cities, however, there is a large difference in major roadway development.

Table 5 presents four travel and roadway mileage ratios for the Texas and other U.S. study cities. The population density values were included to provide a background for the comparison of individual urban areas. The congested Texas urban areas had a population density 30 percent less than the 22 areas outside Texas.

Table 4. 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
Austin	5,300	2,190	12,125	44	18	62
Corpus Christi	1,420	1,400	5,965	24	23	47
Dallas	22,575	8,230	49,050	46	17	63
El Paso	3,420	2,915	9,415	36	31	67
Fort Worth	10,725	4,250	29,285	36	15	51
Houston	24,115	10,810	61,660	39	18	57
San Antonio	9,560	4,585	22,240	43	21	64
Texas Avg.	11,015	4,910	27,105	38	20	58
Congested Texas Avg.	14,455	6,010	34,870	41	18	59
Total Avg.	12,765	7,970	33,145	35	25	60

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

DVMT - Daily vehicle-miles of travel.

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

Source: Reference 5.

The freeways in Texas are serving more of the travel demand than is served in other major U.S. cities, and Texas arterials are serving less of the demand. If Texas arterials could be developed to serve the same level of travel as they carry in other U.S. cities, VMT on arterials would increase by 30%, and freeway traffic would decrease accordingly.

The lane-mile ratios (lane-miles per square-mile and per 1000 persons) illustrate an emphasis in Texas of freeways over principal arterials in comparison to other U.S. cities (Figure 11). The freeway density values are only 10 percent less (1.24 vs. 1.40) in the congested Texas cities than in the other U.S. cities, while the principal arterial value is 35 percent less (1.35 vs. 2.12).

The lane-miles per 1000 persons ratio also illustrates a greater reliance on freeways to provide travel mobility in Texas than in areas outside Texas.

Table 5. Summary of Freeway and Principal Arterial Travel Frequency and Density Statistics, 1986.

Urban Area	Pop. (1000)	Pop. Density (persons/ sq. mi.)	Lane-Miles Per Square Mile		Lane-Miles Per 1000 Population		VMT Per Person		VMT Per Sq. Mi.	
			Frwy	Prin. Art.	Frwy	Prin. Art.	Frwy	Prin. Art.	Frwy	Prin. Art.
Outside Texas Avg.[1]	1,745	2,370	1.40	2.12	.61	.92	6.95	5.07	16,705	11,740
Austin	470	1,400	1.25	1.22	.89	.87	11.28	4.66	15,820	6,535
Corpus Christi	270	1,540	.97	1.83	.63	1.19	5.26	5.19	8,115	8,000
Dallas	1,895	1,345	1.16	1.19	.87	.89	11.91	4.34	16,010	5,835
El Paso	490	2,580	1.82	4.24	.70	1.64	6.98	5.95	18,000	15,340
Ft. Worth	1,120	1,350	1.17	1.01	.87	.75	9.58	3.79	12,920	5,120
Houston	2,800	1,750	.94	1.22	.54	.70	8.61	3.86	15,070	6,755
San Antonio	1,050	2,140	1.65	2.10	.77	.98	9.10	4.37	19,510	9,355
Texas Avg.	1,155	1,730	1.28	1.83	.75	1.00	8.96	4.59	15,065	8,135
Congested Texas Avg.	1,465	1,595	1.24	1.35	.79	.84	10.10	4.20	15,865	6,720
Total Avg.	1,605	2,215	1.37	2.05	.65	.94	7.43	4.95	16,310	10,870

Note: Congested Texas cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio.
VMT - Daily Vehicle-Miles of Travel.

[1]This is the average for 22 large U.S. cities located outside of Texas, generally in the south, southwest and west.

Source: Reference 5.

The lane-mile per square mile ratios further reflect the dependence of Texas cities on the freeways. The freeway density value for congested Texas cities is only 10 percent below that of U.S. cities (1.24 vs. 1.40). However, the arterial value associated with congested Texas cities is 35 percent less than that characteristic of U.S. cities (1.35 vs. 2.12).

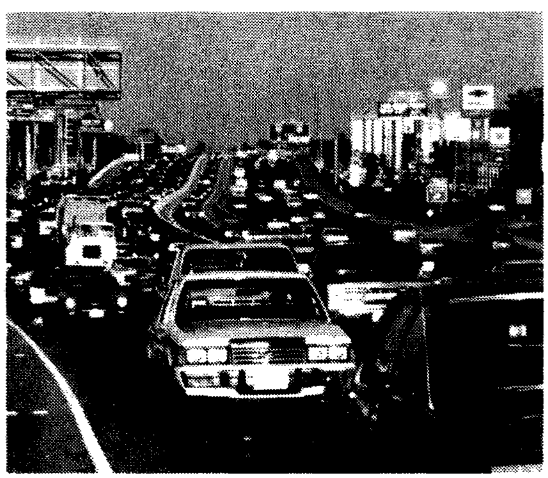


Figure 11. Katy Freeway and Transitway, Houston

Comparison of urban travel between Texas and other U.S. cities emphasizes that, in Texas cities, a disproportionate share of traffic is served by freeways while relatively little of the travel is served on the principal arterials.

A Lack of Street System Continuity

The preceding section of this report suggests that, in comparison to cities outside Texas, the arterial street system in Texas is serving a relatively low share of daily vehicle miles of travel. Part of the reason for this is that the street system, in general, lacks continuity.

To illustrate this fact, roadway inventory files were reviewed for Dallas, Fort Worth, and Houston. In this analysis, for an arterial street section to be considered "continuous", it had to possess two characteristics: 1) it had to have a minimum of 4 lanes; and 2) it had to have that cross section for a continuous distance of at least four miles.

Table 6 summarizes the data for the 3 Texas cities. The principal arterial street systems in Dallas, Fort Worth, and Houston exhibit a range of continuities. Approximately 85 percent of the Dallas urban area principal arterial street system meets the definition of continuous; i.e., it is comprised of 4-lane streets continuous for at least 4 miles. The Houston system, although it has 15 percent more total lane miles than Dallas, has a significantly lower percentage of continuous arterials. The Fort Worth system is less continuous than the Houston system. Although enhanced continuity is not the only means to increase the attractiveness of the arterial street, these values suggest that meaningful opportunities exist for enhancing mobility through providing greater continuity to the arterial street system.

Table 6. Urban Area Principal Arterial Street System Characteristics, Selected Major Texas Cities

Principal Arterial Street Characteristics	Dallas	Fort Worth	Houston
Lane Miles, Total	1,680	840	1,955
Avg. Number of Lanes	4.5	3.9	3.9
Continuous[1] Lane-Miles	1,420	300	1,150
% Continuous Roadways	85	35	60
Average Continuous Number of Lanes	5.5	4.2	4.4
Median Value for Length of Continuous Section (miles)	8.1	6.6	8.3

[1]Continuous is defined as having at least a 4-lane section over a distance of at least 4 miles.

Source: Houston-Galveston Regional Transportation Study Roadway Inventory and North Central Texas Council Of Governments major Thoroughfare Link File

A major reason that arterial streets in Texas do not serve more travel is that they lack system continuity. Only 60 percent of the arterial lane-miles in Houston are on streets that have at least 4 lanes over a distance of at least 4 miles.

Arterial Street Continuity - A Case Study

The fact that arterial street systems in Texas lack continuity and serve a relatively small portion of travel demand has been exhibited. To better define this occurrence, a case study was undertaken. A section of north Dallas having a relatively good arterial street system was compared to a section of west Houston; the west Houston area evaluated has a less than desirable arterial street system.

A 60 square mile (six mile by ten mile) corridor was outlined in both north Dallas and west Houston (Figure 12). These corridors contain significant suburban activity centers (Greenway Plaza and the Galleria area in Houston, and the Park Central and Galleria areas in Dallas) and a variety of residential patterns. The study corridors begin two to three miles from the central business district (CBD) and extend ten miles outward. The Dallas corridor is generally centered on the North Dallas Tollway, with the Houston corridor centerline located between the Katy (I-10W) Freeway and the Southwest (US 59S) Freeway. Estimated population and employment statistics for these corridors are included in Table 7. The freeway and arterial street systems in these two corridors were examined to determine their representative width (number of travel lanes) and length. The west Houston freeway system was more extensively developed (24 miles averaging 8.5 lanes) than the north Dallas corridor (19 miles averaging less than 6 lanes). The major and minor arterial street classification also contained more mileage in Houston (185 miles) than Dallas (100 miles). Considering the population and employment values for these two corridors (Table 7), however, the disparity in street and freeway mileage was expected.

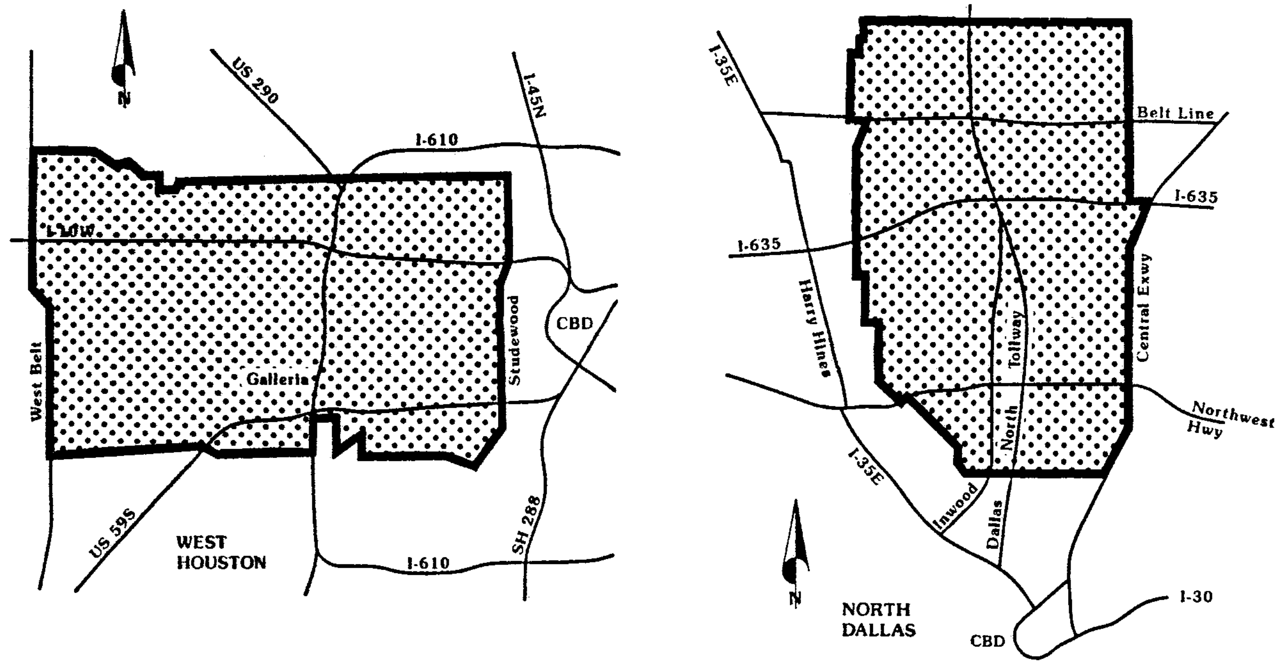


Figure 12. Location of West Houston and North Dallas Corridors Evaluated in the Case Study

In the north Dallas area, which has an excellent arterial system, 56 percent of the vehicle miles of travel are served on the arterials. In the west Houston area, with a less desirable arterial system, 44 percent of the VMT is served on arterials. These data suggest that, when properly developed, the arterial system will serve more trips.

Table 7. Population and Employment Data For Case Study Corridors -- West Houston and North Dallas

Area Statistic	West Houston	North Dallas
Study Area (sq. mile)	60	60
Population (1000)	295	205
Population Density (persons/sq.mi.)	4,800	3,400
Employment (1000)	350	160
Employment Density (employees/sq.mi.)	5,700	2,600

Note: Study Corridors were ten miles long and six miles wide and began two to three miles outside of the central business district.

Source: U.S. Census Bureau

The principal difference in the arterial street systems between the two corridors is illustrated in Table 8. The north Dallas system is characterized by six-lane arterial streets, while west Houston has predominately four-lane arterials. The difference in continuous length of these systems also indicates the disparity in total roadway network capacity. More than 50 percent of the arterial lane-miles in Dallas have a six-lane cross section continuous for more than four miles. If the sections of four-lane arterial are included, 67 of the 100 arterial route miles (67 percent) are both four lanes or more in width and four miles or longer in length.

Table 8. Arterial Street System Lane-Miles By Category For Case Study Corridors -- West Houston and North Dallas

Arterial	Arterial Width 2-Lane	4-Lane	6-Lane	Over 4 Miles in Length	Total
West Houston					
0-2 mi.	45LM	205LM	35LM	----	285 lane-miles
2-4 miles	30LM	145LM	90LM	----	265 lane-miles
4-6 miles	--	90LM	45LM	----	135 lane-miles
6-8 miles	15LM	--	--	----	15 lane-miles
TOTAL	90LM	440LM	170LM	150	700 lane-miles
North Dallas					
0-2 miles	15LM	50LM	75LM	----	140 lane-miles
2-4 miles	--	45LM	60LM	----	105 lane-miles
4-6 miles	10LM	--	130LM	----	140 lane-miles
6-8 miles	--	--	125LM	----	125 lane-miles
TOTAL	25LM	95LM	390LM	265	510 lane-miles

Note: LM means lane-mile.

Source: Houston-Galveston Regional Transportation Study Roadway Inventory and North Central Texas Council Of Governments Major Thoroughfare Link File

In the north Dallas area, the predominate arterial street has 6 lanes and is 4 to 6 miles in length. In the west Houston area, the predominate arterial street has 4 lanes and is less than two miles in length.

The west Houston corridor is characterized by four-lane arterials that are continuous for less than four miles. More than 65 percent of the Houston lane-miles in Table 8 are on four- or six-lane arterials that exist as constant cross sections for less than four miles. Less than 30 percent of the route miles (51 of 185) are both four lanes or more in width and at least four miles long.

The result of these street patterns is that a higher percentage of arterial travel (which is not necessarily the same as demand) in the north Dallas area is served by arterial streets (Table 9). In fact, if the Dallas area in this case study served the same percentage of traffic on its

Table 9. Vehicle-Miles of Travel, Case Study of West Houston and North Dallas

Roadway	North Dallas	West Houston
Freeways And Freeway Travel		
Miles (lane-miles)	19 (110)	24 (205)
Lanes/Mile	5.8	8.5
Daily VMT (1000)	1,815	4,600
Percent of Freeway and Arterial VMT	44%	57%
VMT/Lane-Mile	16,500	22,450
Arterials And Arterial Travel		
Miles (lane-miles)	101 (510)	184 (700)
Lanes/Mile	5.1	3.8
Daily VMT (1000)	2,330	3,525
Percent of Freeway and Arterial VMT	56%	43%
VMT/Lane-Mile	4,570	5,040

If the Dallas arterial streets in this case study served the same percent of vehicle-miles of travel as in Houston, travel served by the Dallas freeways would need to increase 30 percent to serve the same total demand. Thus, enhancing mobility on the arterial streets can divert trips from the freeways.

does Houston, VMT per lane-mile on the Dallas freeways would increase 30 percent, from 16,500 to 21,500. A conclusion is that a well developed arterial street system is capable of serving a higher percentage of total traffic and diverting trips from the freeways.

Funding Sources

As shown previously, in addressing the urban mobility problem in Texas from the supply side, it will be necessary to: 1) expand the urban freeway system; 2) implement cost effective mass transportation improvements; and 3) expand the urban arterial street system. Substantial and dedicated funding is currently available for the freeway and transit part of the solution. The same is not generally true for the arterial street component.

This section presents cost data that define the general magnitude of expenditures for different purposes in the large Texas urban areas. The values presented are intended only to present "ballpark" indications of the level of spending. Specific numbers are difficult to obtain in a consistent and comparable manner; expenditures in any given area can vary considerably over time, and it is difficult to accurately relate the geographical area and population to the expenditures.

The Urban Freeway System

A dedicated fuel tax (Figure 13) provides the Texas State Department of Highways and Public Transportation (SDHPT) with a significant source of funds not present at the county or municipal government level. Between 1980 and 1986, on a statewide basis, the SDHPT spent $8.6 billion for capital improvement to their roadway system, an average of $1.2 billion per year (9).

Total expenditures by the State Department of Highways and Public Transportation for both construction and maintenance in the counties containing the major urban areas totalled approximately $900 million in 1986 (Table 10). Data from a second source (10) suggest that, of the expenditures shown in Table 10, approximately 70 percent of the funds were for construction on freeways and expressways, and about 25 percent were for construction on the principal arterial street system. It should be kept in mind that, on a county basis, expenditures can vary substantially in different years; thus, the totals for all the areas are probably more representative of expenditure levels than are the expenditures shown for any one specific urban area. As a result, individual county expenditures are not shown in Table 10.

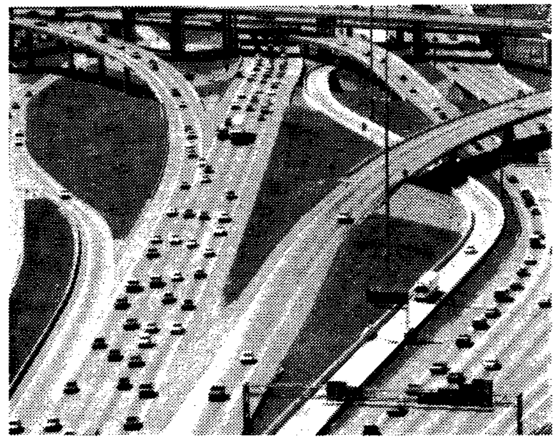


Figure 13. Gulf Freeway and Transitway, Houston

In general, dedicated funding sources exist to construct freeways and to provide transit services in the large Texas cities. However, dedicated funding sources are generally not available for arterial improvements.

The data suggest that the State expended approximately $23 per capita for maintenance in 1986.

Public Transportation

Dedicated sales tax revenue now is in place to support public transportation in the large Texas cities. Relevant data are summarized in Table 11. It should be noted that the reason capital expenditures are relatively low is that most of the transit authorities do not yet have approved long-range plans; it is anticipated that, once those plans are finalized and adopted, capital expenditures for transit will increase markedly. As a result the table shows both revenue per capita and capital expenditures per capita.

Table 10. Estimated 1986 Expenditures by State Department of Highways and Public Transportation in Major Urban Counties

Urban Counties[1]	Estimated Population[2] (000)	Freeway Construction		Arterial Construction	
		Total ($ millions)	Per Capita ($)	Total ($ millions)	Per Capita ($)
Total or Average	8095	$635	$78	$211	$26

[1]Data included for Travis, Nueces, Dallas, El Paso, Tarrant, Harris and Bexar Counties.

[2]Estimated 1986 urban area population as reported in reference 5.

Source: Analysis of data presented in references 9 and 10. Assumes that 75 percent of state expenditures were for freeways and expressways and 25 percent for arterial streets.

In 1986 in the large urban counties in Texas, the State Department of Highways and Public Transportation expended approximately $80 per capita for freeway construction and $25 per capita for principal arterial street construction.

Table 11. Estimated 1987 Expenditures on Public Transportation in the 7 Large Texas Cities

7 Large Cities[1]	Estimated Population[2] (000)	Revenue Per Capita	Capital Expense Per Capita	Operating Expense Per Capita
Total or Avg.	8,095	$64	$9	$39

[1]Includes data for Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston and San Antonio.

[2]Estimated 1986 urban area population as reported in reference 5.

Source: Derived from data in references 11 and 5.

In the large Texas cities, transit generates total revenues of approximately $65 per capita. Most of this is expended on operating expenses.

Local Expenditures on Streets and Roads

Included in this category are expenditures of public funds made by the county and by all cities with population greater than 50,000. Not included are expenses incurred by private developers in providing streets. Table 12 summarizes data on expenditures by local government on all city streets in 1986.

All Funding Sources

The data in Tables 10 through 12 are summarized in Table 13. Expenditures by the state alone exceed expenditures on streets and roads made by all local governmental agencies.

New Funding Sources

The Principal Arterial Street System (PASS) begun by the SDHPT in 1987 represents an increase in the commitment to provide funding to increase urban mobility on arterial streets. In this program, the SDHPT will fund selected local agency roadway improvement projects to enhance street system capacity. Approximately $35 to $40 million in new state funds will be devoted to this program annually and will be spent in cities having a population greater than 200,000 (12).

The Harris County (Houston) Metropolitan Transit Authority has committed to spend one-fourth of its sales tax revenue until the year 2000 on arterial street construction and rehabilitation projects as an element of the long-range plan. The estimated $40 million per year will facilitate construction of street widening

Table 12. Estimated 1986 Expenditures by Cities and Counties on Streets and Roads

7 Large Cities[1]	Estimated Population[2] (000)	Freeway Construction		Arterial Construction	
		Total ($ millions)	Per Capita ($)	Total ($ millions)	Per Capita ($)
Total or Average	8095	$432	$53	$189	$23

[1]Includes expenses by the major county and all local cities with populations greater than 50,000 in the Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston and San Antonio areas.

[2]Estimated 1986 urban area population as reported in reference 5.

Source: Derived from data in references 9 and 5.

While a dedicated funding source does not exist for street improvements, in the large Texas urban areas approximately $50 per capita was spent on capital street improvements by local governments in 1986.

Table 13. Estimated Annual Expenditures on Transportation Capital Improvements in Large Urban Areas[1] in Texas

Type of Transportation Improvement	Annual Expenditures Per Capita		Expenditures Per Lane Mile[2]	% of VMT
	Total	% of Total		
Freeways and Expressways[3]	$ 78	47%	$108,000	38%
Public Transportation[4]	$ 9	5%	NA	NA
Local Streets and Roads[5]	$ 79	48%	$ 91,000	20%[6]
TOTAL	$166	100%		

[1]Includes data for the Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston and San Antonio.

[2]Non-weighted average of data included in reference 5.

[3]Expenditures by the State Department of Highways and Public Transportation.

[4]Expenditures by transit agencies. These expenditures are low relative to total revenues since long-range transit plans have not been approved in many urban areas.

[5]Expenditures on principal arterials by SDHPT and expenditures on all streets and roads by counties and cities with populations in excess of 50,000.

[6]Principal arterial VMT only.

Not including expenditures by developers and recognizing that transit capital expenditures will increase markedly in the near future, roughly half of current capital transportation expenditures are made on urban streets and roads other than freeways.

and grade separation projects on local jurisdiction roadways.

Considerations

The comparison of transportation systems in Texas and other U.S. cities quantified the difference in the percentage of vehicle travel served on arterial streets. The freeway and principal arterial street systems carry a more equivalent share of the vehicle-miles of travel in major cities outside Texas due to the more extensive arterial systems developed in these areas.

The disparity in street and freeway funding in major Texas cities suggests that freeways have been relied upon to carry an overly large portion of the travel load. Transportation system improvement programs have focused on the major freeway corridors with less funding for arterial streets. While this situation is beginning to change with new programs and funding sources, arterial street funding in Texas continues to lack a dedicated funding source, and the expenditure by all local agencies are less than the amount expended by the state in the large urban areas.

If the arterial street system in the major congested cities in Texas (Austin, Dallas, Fort Worth, Houston and San Antonio) were to carry the additional vehicle-miles of travel necessary to increase the percentage of total trips carried on arterial streets to the average value for the low and moderate density study cities outside Texas, it would be the equivalent of handling either: 1) approximately five years of traffic volume growth; or 2) reducing freeway volumes by over 20 percent if the additional trips served were all diverted from freeways. To accomplish this would also require a significant investment in arterial street construction, but this construction would be compatible with the extensive freeway construction efforts in the major cities; arterial street development would provide more alternative travel routes, relieving the freeway system of some shorter length trips. Each component of the urban area roadway system could then serve the trip patterns it was designed to handle.

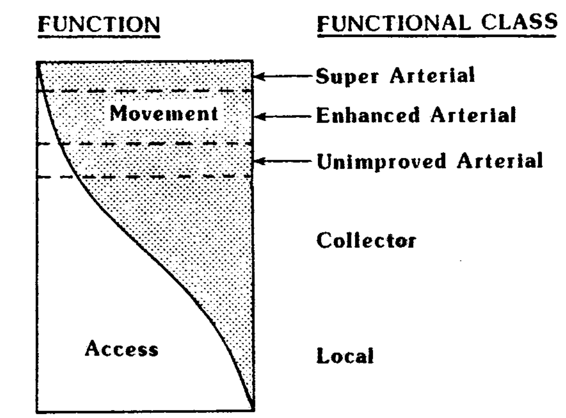
In considering the development of the arterial street system, it should be realized that, while money is always a concern, significant and dedicated funds are available for freeway construction and public transportation development. Similar dedicated funding does not currently exist for arterial street development.

IV. CHARACTERISTICS OF FUNCTIONAL ARTERIAL SYSTEMS

The intent of this section of the report is to define the concept of functional classification of roadways. Each functional class is described, and how super arterial streets fit into the concept is illustrated. An intent is to show how, ideally, an urban street system would be planned and designed. This can be contrasted to the data presented previously describing the extent and layout of the arterial street systems in Texas.

Functional Classification

The concept of functional classification (13) recognizes that the functions of movement and access are mutually exclusive. A high level of access interferes with movement. Conversely, high-speed and high-volume movement severely restrict access and egress. Functional roadway classification and design recognizes that a given facility must be designed according to the degree to which it is to serve these mutually exclusive functions -- access or movement. As illustrated in Figure 14, three general functional classes are recognized (13).



Source: Reference 14.

Figure 14. Basic Functional Classification for Urban Thoroughfare

A super arterial represents the upper end of the arterial street functional classification. The intent of such a system of roadways is to move traffic and relieve congestion on the freeway system.

Arterials are those streets which primarily serve the movement function and longer trips. At the other extreme, local streets are intended to accommodate the access function and shorter trips, and movement is provided only to and from a higher level facility. Collectors on the other hand are intended to serve both access and movement; consequently, the application of desirable design standards is much more difficult to define for this class of street than for either arterials or locals. It is also important to note that functional classification is a continuum from primarily access to principally movement; there are no distinct boundaries between the functional classes.

The four functional highway systems for urban areas are defined (13) as follows:

- Principal Arterial System
- Principal Arterial Plus Minor Arterial System
- Collector Roads
- Local Road System

Arterial

The principal arterial system serves the major centers of activity in an urban area. Almost all fully and partially controlled access facilities are a part of this functional class. The urban arterial system (Figure 15) carries most of the trips entering and leaving the urban area, as well as most of the through movements bypassing the central city. This system provides continuity for all rural arterials that intercept the urban boundary. In addition, significant intra-area travel, such as between the central business district (CBD) and outlying residential areas, between major inter-city communities, and between major suburban centers, is served by this class of facility. Frequently, the arterial system carries important bus routes.

Ideally, service to abutting land should be minimized in the arterial system. Realistically, it is recognized that many arterial streets have a great deal of access to serve abutting properties. This situation restricts the level of traffic movement that can be realized on these facilities. Restriction of access offers a means to enhance the movement function of the arterial streets.

Collectors

The urban collector street system provides both land access service and traffic circulation within residential neighborhoods and commercial and industrial areas. It differs from the arterial system in that facilities on the collector system may penetrate residential neighborhoods, distributing trips from the arterials through the area to their ultimate destinations. The collector street also collects traffic from local streets in residential neighborhoods and channels it into the arterial system. In the central business district, and in other areas of similar development and traffic density, the collector system may include the entire public street grid (13).

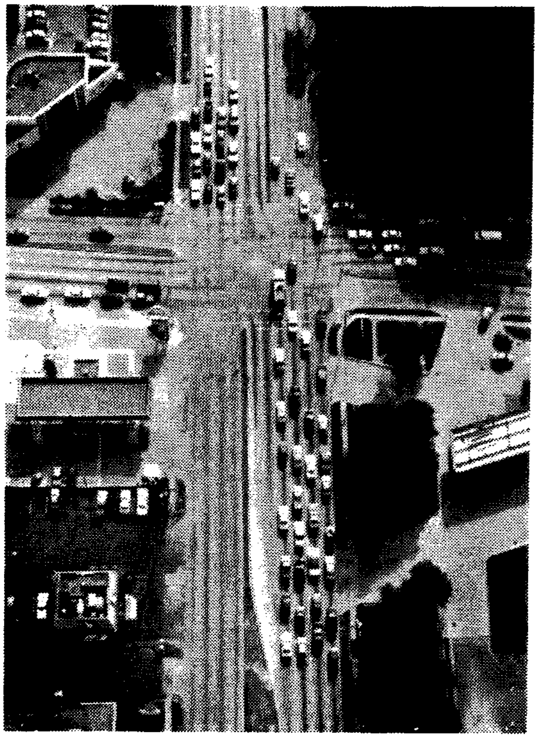


Figure 15. Major Arterial Street Intersection

The primary role of the principal arterial should be to move traffic rather than to provide access to abutting property.

Local

The local street system comprises all facilities not in one of the higher systems. It primarily accommodates direct access to abutting lands and connections to the higher order systems. It offers the lowest level of mobility and usually contains no bus routes. Through-traffic movement usually is deliberately discouraged (13).

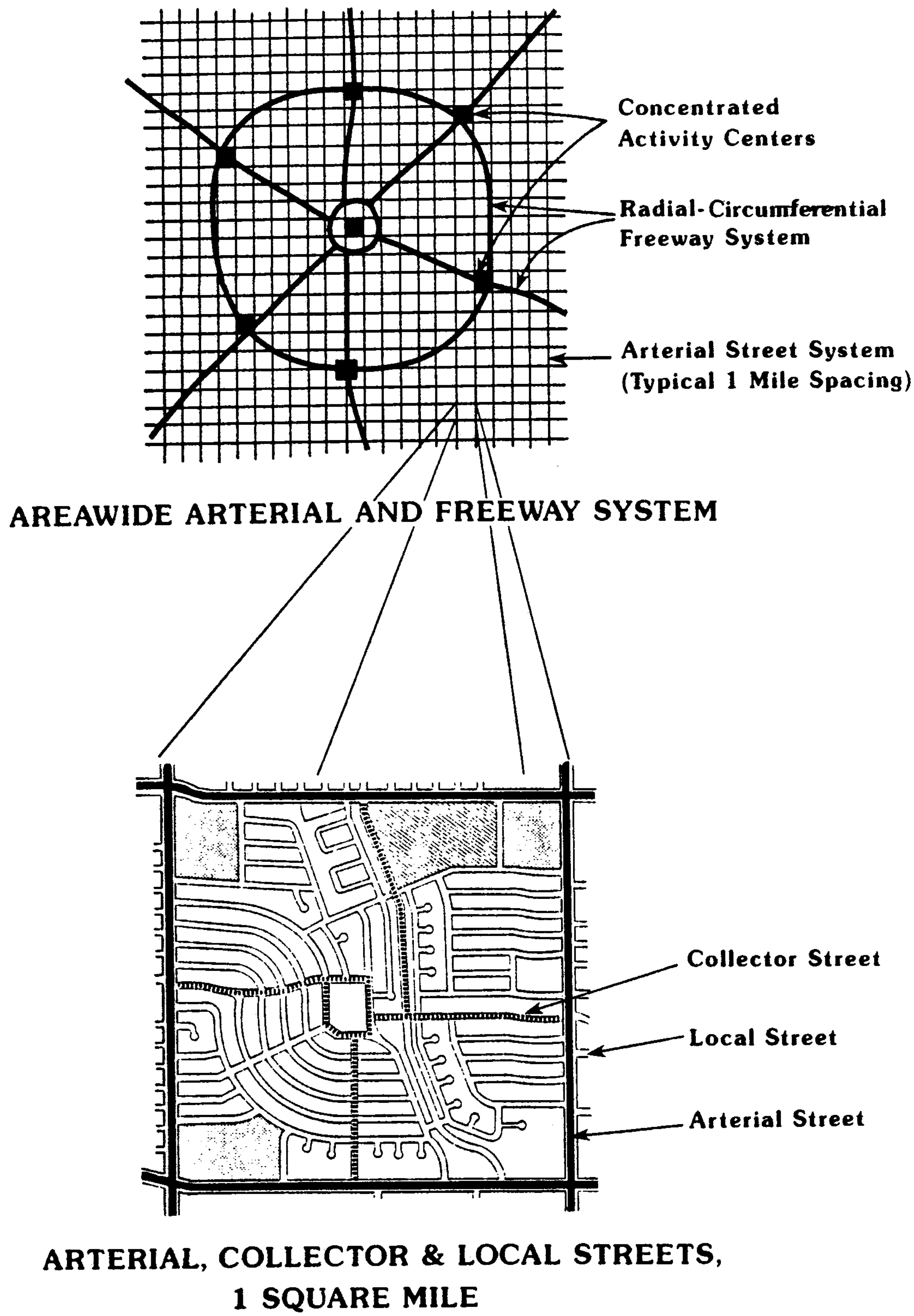
Desirable Arterial Characteristics

"Arterials are expected to provide a high degree of mobility for the longer trip length(s). Therefore, they should provide a high operating speed and level of service" (13). In order to accomplish this objective, arterials should have the following characteristics:

- Continuity throughout the urban area
- High design speed and operational flexibility
- Grade separations where applicable
- Long, uniform signal spacing
- Mid-block cross-section incorporating a non-traversable median and marginal buffer strips or two-way left turn lanes
- Intersection configurations with separate turn bays and the flexibility to adjust to unforeseen traffic conditions
- Management of unsignalized medial and marginal access
- Pedestrian grade separations as needed

Continuity

Principal arterials should have continuity through the entire urban area. Most minor arterials should also have continuity throughout the entire urban area and into the urbanizing fringe. Where discontinuous, a minor arterial should terminate at a principal arterial or another minor arterial. An idealized urban system of freeways, principal arterials and minor arterials is shown in Figure 16. As noted in the previous section of this report, lack of continuity is a major problem with the Texas arterial street systems.



Source: Adapted from Reference 13.

Figure 16. Idealized Urban System of Major Roadways

A well developed system of continuous urban arterial roadways is important in providing areawide mobility

High Design Speed

Design speed is the principal parameter which controls the geometrics of arterial streets. AASHTO (13) states ".... they should provide a high operating speed and a high level of service." Arterials must be designed to operate safely and efficiently at two different speeds, because traffic conditions are different in the peak periods and off-peak periods. The following speeds are appropriate for urban arterials:

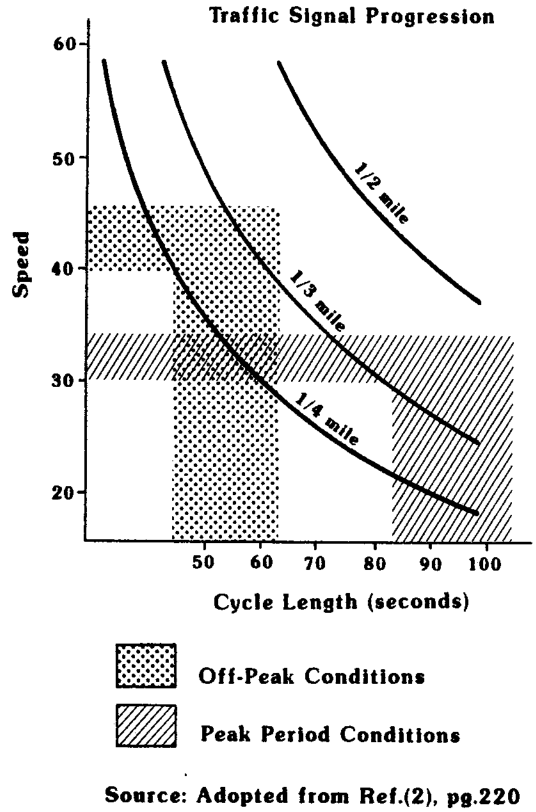
Functional Design Class	Design Speed (MPH) Peak	Off-Peak
Primary Arterial	35-40	45-55
Major Arterial	30-35	45-50
Minor Arterial	30-35	40-45

The spacing of signalized intersections is an important concern in optimizing the movement of traffic.

Signalized Intersection Spacing

Signalized intersections which will facilitate traffic progression at both peak and off-peak speeds must be established on urban arterials if they are to serve their movement function. Figure 17 illustrates the signal spacing required to achieve efficient traffic progression at different speeds and cycle lengths.

Figure 17 shows that signal spacings of about one-half mile are required in order to develop timing plans for efficient traffic progression for both peak and off-peak conditions. Research (14) has indicated that total user costs decline as signal spacing increases. At high volumes, the cost continues to decrease up to uniform signal spacing of one-half mile or longer. Even for low volumes, total user costs were shown to increase rapidly for spacing of less than one-quarter mile. Also, efficient traffic progression through a signal system reduces fuel consumption by as much as one-half and reduces auto emissions as compared to stop-and-go conditions.



Source: Reference 14.

Figure 17. Relationship Between Progression Speed, Cycle Length and Signal Spacing

To emphasize the movement function of the arterial street, close attention must be given to the spacing of signalized intersections.

Suggested signalized intersection spacings and progression criteria by functional class are as follows:

Functional Design Class	Speed (mph)	Min. Signal Spacing (mi.)	Off-Peak Progression Min. Prog. Speed (mph)	Min. Prog. Band as % of Cycle
Principal Art.	55	1/2	>45	>30%
Major Art.	45-50	1/3	>40	>45%
Minor Art.	40	1/4	>35	>30%

Cross-Section

Major roadways can be designed with a non-traversable median which can be landscaped to enhance delineation. Left-turn bays should be required wherever there is an opening in the median. Alternatively, two-way left turn lanes can be provided. In either event, effective accommodation of left turning movements is an important concern.

Intersections

All intersections on arterial streets, signalized and unsignalized public streets, and private access drives should have turn bays. Turn bays should be designed to limit the speed differential to a maximum of 10 mph.

Intersections of two principal arterials, a principal and a minor arterial, or two minor arterials should be designed with the provision for dual left-turn lanes. If original construction is with a single left-turn lane, the median width should be sufficient (at least 28 feet) to allow the addition of the second lane at a later date. A single left-turn bay should be required at all other intersections, including unsignalized median openings designed for either a left-turn ingress or for a left-turn egress. All left-turn bays need to be of sufficient length to allow deceleration to occur after the vehicle leaves the through traffic lane plus storage to accommodate all turning vehicles with at least a 90 percent probability.

Right-turn bays should be required at all arterial intersections, public and private, signalized and unsignalized. The turn bay should be designed so as to limit the speed differential between the turning vehicle and through vehicles to 10 mph or less. Intersections of two principal arterials, a principal and a minor arterial, and two minor arterials should provide channelization of right turn lanes. The inside radius of the turning roadway should be at least 75 feet on minor arterials and 100 feet on principal arterials.

Access Management

Access management criteria should be developed and implemented in order to preserve the movement function of an arterial. These criteria must include standards for the location, spacing, and design of access (public and private) which may be constructed between the signalized intersections.

A minor access point should not be located within the functional area of a major intersection (14). The size of this intersection area is related to traffic speed and queue storage requirements. At arterial street speeds, this functional area will extend 500 feet, or more, upstream from the intersection and about 300 feet downstream.

V. WHAT CAN BE DONE TO ENHANCE EXISTING ARTERIALS

The preceding section of this report described the concept of functional classification. It illustrates desirable approaches for laying out an urban roadway system. This section discusses actions that can be taken to increase the movement function of an arterial roadway; these are approaches that might be used in Texas to make our street systems more closely resemble the desirable functional street layout.

Enhancements to existing arterial streets in urban areas can be placed into two basic categories which are defined as follows:

(1) Super Arterials, and
(2) Enhanced Arterials.

The concept of a Super Arterial would be as close as possible to that of a freeway without the complete control of access. It would represent a new type of roadway system for Texas cities that would substantially upgrade the traffic movement capabilities of existing arterial street systems. The physical design of the super arterial can vary by location within the urban area. The key is that this is a regionwide system of high-capacity arterial streets.

The concept of Enhanced Arterials would provide the type of arterial that many cities have already employed along at least some routes. The arterial provided would be the best possible facility given the existing rights-of-way and access control capabilities. Enhanced arterials can be viewed as individual corridor improvements rather than part of a regionwide system of arterial improvements, although in some locations the enhanced arterial may also be a part of the regionwide system of arterial super streets.

Super Arterials

A Super Arterial would be constructed with the aim of providing a facility geared to the movement of traffic, with the main difference between it and a freeway being one of access control. The basic desirable characteristics of a Super Arterial are listed below. It is recognized that not all of these characteristics can be provided on all parts of the super arterial regional roadway system.

1. Part of a system of regional, high capacity arterial streets
2. Six through lanes minimum and eight through lanes desirable
3. Grade separations with other super arterials, railroad grade crossings, etc.
4. Signalization improvements to facilitate progressive movement through the system
5. Signal spacing of 2000 feet minimum
6. Continuous median between signalized intersections
7. No parking
8. Access restrictions
9. At-grade signalized intersections designed with separate left turn lanes and right turn lanes (avoidance of left turns when possible).
10. Special transit loading and unloading areas
11. Minimum length of four miles

As previously stated, the Super Arterial would represent a new type of system of facilities that would be designed to move large volumes of traffic and serve travel throughout the region. It represents a new concept in Texas, and obtaining the required amount of right-of-way and control of access will be difficult. The provision of this type of street system, however, could greatly add to urban mobility.

Enhanced Arterials

The Enhanced Arterial would be the type of arterial that is already in some corridors in many cities. It is an arterial street that has been upgraded to handle heavy traffic in a given corridor through a range of improvements, including the following:

- Signalization improvements
- Increased intersection capacity
- One-way operation
- Reverse or unbalanced flow
- Access restrictions
- Transit improvements
- Street widening
- Parking restrictions

Description of Alternative Arterial Street Improvements

A brief discussion of the various improvement techniques that could be utilized with either the Super Arterial or Enhanced Arterial is presented in this section.

New Arterial Streets To Provide Continuity

Previous data have illustrated that lack of continuity is a major concern in assessing the ability to enhance the capacity of arterial streets. Improvements in this category would involve filling in the "missing links" to add continuity to the arterial street system. These improvements offer the greatest potential increase in system capacity. However, the political, institutional, and funding problems associated with acquiring new right-of-way also are associated with these relatively expensive improvements.

Grade Separations

Construction of a grade separation for large volumes of intersecting traffic can result in a significant capacity improvement. The largest through movement can be taken through the intersection via the grade separation, and the other through movement can be given preference in a signalization arrangement. Special auxiliary lanes can be designed to handle the right and left turn movements. The right-of-way requirements and access control at such an interchange will no doubt present special problems that will have to be studied.

Signalization Improvements

Signalization improvements could include removal of unwarranted signals, the installation of computerized signal systems, and the overall optimization of signal operations. When the signalization is included in the overall optimization of an arterial facility (Super Arterial or Enhanced Arterial), signal improvements can generally be expected to reduce delay and increase capacity.

One-Way Operations

The use of one-way operation could be utilized to improve traffic flow on either the Super Arterial or the Enhanced Arterial. The availability of the necessary roadway facilities for the one-way operation is a key consideration.

Access Management

Good access management is a key to the success of either type of arterial development. It will be especially critical to the Super Arterial concept since movement of traffic will have precedence over access. Specific problems will be encountered in controlling access along the facility as well as at the intersections.

Transit Improvements

The main consideration relative to transit improvements is to make those additions that will facilitate transit operations and not reduce the ability of the facility to move auto traffic. Thus the location and placement of transit stops is an important consideration. The use of an area outside the traveled way in the middle of a block or on the far side of the intersection approach should be chosen for transit stops. The development of shelters and pedestrian flow patterns need to be considered.

Increased Intersection Capacity

The capacity of an arterial street is often restricted by the capacity of a critical intersection. Often this problem can be corrected by the addition of left-turn bays which will often reduce delays and accidents. In some cases it may be necessary to convert single lanes to dual left-turn lanes to provide the needed left turn capacity. In other cases, it may be possible to serve left turns by designing an "around the block" system of right turns.

The additions of channelized right-turn bays will also increase capacity and contribute to traffic safety. The provision of these facilities is a principal method of upgrading existing urban arterial streets.

Street Widening

If the necessary right-of-way can be obtained, the provision of additional lanes by widening the street is most effective. It is desirable to obtain a uniform cross section on arterials by obtaining the desired right-of-way and widening where necessary to provide a common pavement width.

Reverse Or Unbalanced Flow

If an unbalanced flow (minimum of twice as much traffic in peak direction as in off-peak direction) exists, it may be desirable to provide for special unbalanced flow (for example three lanes in peak direction and two lanes in off-peak direction). This is often a good way to fit an odd sized street to a heavy directional type of peak flow.

Overview of Improvements

A summary of the potential improvements that could be realized in arterial street development is presented in Table 14.

VII. CONCLUSIONS

That Texas has serious mobility problems in its large urban areas is beyond question, and all indications suggest these mobility problems will get worse unless something is done to change the situation. The supply side of mobility furnishes highway and street facilities and public transit services. The demand side is trips generated as a result of our life style (8 a.m. to 5 p.m. work habits for example), our general affluence, and decades of investment in low density housing and concentrated activity centers supplying jobs, goods, and services. Unless the nation's economy drastically declines, there is nothing that is likely to happen in the foreseeable future that will affect the continuation of our current lifestyle and the demand for increased amounts of highway and street services.

In large urban areas, the backbone of the highway and street network is the freeways and arterial streets. These

Table 14. Cost and Effectiveness of Alternative Arterial Improvements

Alternative Improvement	Capacity Increase	Accident Reduction	Approximate Cost
New Arterial Streets To Provide Continuity	Very Significant	N.A.	$ 2,000,000 to $ 5,000,000/Mile
Signalization	10-25%	0-15%	$ 50,000 to $ 1,500,000/mile
One-way Operation	20-50%	0-60%	$ 60,000/mile
Reverse Flow	20-50%	0-30%	$ 180,000/mile
Added Intersection capacity (left and right turn lanes)	10-25%	0-25%	$ 250,000 to $ 2,000,000/intersection
Access Management	5-10%	0-50%	$ 250,000 to $2,000,000/mile
Street Widening	25-50%	0-50%	$ 500,000 to $1,000,000/lane-mile
Grade Separation	25-50%	40-50%	$3,000,000 to $5,000,000 each
Transit Related	3-10%	None	$ 10,000 to $ 50,000/turnout

Notes: 1. The costs shown for these improvements are construction costs. Where applicable, right of-way costs need to be added.
2. The capacity increases shown in this table are not necessarily additive.

Sources: References 14,15,16,17 and TTI analysis.

This table provides an estimate of the "ballpark" ranges associated with alternative arterial street improvements. In the proper environment, all these improvements can be highly cost effective.

facilities typically carry 60 percent of the total vehicle miles of travel (VMT) while accounting for only 7 percent of the length of the total highway and street network.

Although a significant amount of construction work is in progress on the freeways in the major urban areas of Texas, this work is primarily aimed at upgrading existing sections of freeways and is largely contained on existing rights-of-way. The overall system of freeways in these major urban areas is in place, and any new facilities would require purchasing right-of-way and long periods of time to complete.

Thus it is believed that the most effective means of providing additional roadway capacity for major traffic movement in the large urban areas of Texas is by increasing the capacity of the principal arterials. These facilities can run north-south or east-west and can be made to carry heavy traffic loads.

In order to achieve the necessary capacity, it is believed that a large number of these facilities will have to be Super Arterials forming a regionwide system of high-designed arterials with minimum lengths of 4 to 5 miles. Studies are needed to evaluate the potential for building such facilities in the major urban areas of Texas.

In places where it is not possible to build the Super Arterial, then the arterials will need to be of the Enhanced Arterial type. Studies are also needed to determine the additional capacity that can be gained by developing this type of facility to its maximum potential.

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