CHANGES THAT ADVANCED TRAFFIC MANAGEMENT SYSTEMS ARE EXPECTED TO BRING TO TEXAS

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SUMMARY

Advanced Traffic Management Systems (ATMS) rely heavily on the state-of-the-art computer technology and the latest innovations in electronics and communications to manage traffic in high use areas. ATMS is not just technology, however, but includes advanced management strategies to help increase roadway efficiency. A well-designed ATMS program merges technology and management techniques together to improve the mobility and safety of travel.

The enhanced information environment provided through ATMS enables individuals to make better travel decisions. ATMS incorporates accurate and reliable surveillance and detection systems plus effective incident management and control strategies. The emphasis on improved operations must accompany a continued commitment to maintenance and new construction within the transportation infrastructure.

There are many inefficiencies in the present freeway system resulting from steadily increasing traffic volumes. This traffic growth has been much faster than construction (for providing more capacity) can keep up with. In Texas, some of the primary causes of traffic growth are increasing state population, affordability of automobiles and gasoline, increase of women in the work force, population and work centers shifting toward the suburban areas, increasing number of households, slowing down of highway construction, movement of industry and jobs into the state, and increasing numbers of older drivers.

ATMS was first introduced to Texas in the early 1960s with the Gulf Freeway Surveillance and Control System in Houston. Historically, operations research in the state has been extensive, but not the large scale implementation of operations technology. Only recently, as the traditional solutions to traffic congestion by constructing more roadways and lanes became increasingly difficult to implement, has more emphasis been placed on traffic operations. The application of ATMS technology is quickly becoming the preferred Texas approach to handling the traffic congestion problem in the large urban centers.

In Houston, Dallas, Fort Worth and San Antonio, ATMS projects are being planned and implemented to answer the challenges presented by urban traffic congestion. Common elements of all these projects are video surveillance, incident detection systems, traffic control centers, changeable message signs and provisions of real-time traffic information.

There are several issues related to ATMS that could play an important part in the future successes of these projects. One of the key issues is the coordination required among transportation entities for effective areawide traffic management. Another issue is the possible role of the private sector in traffic operations, traditionally a state function in Texas. Funding of ATMS is an issue that must also be considered. Private funding sources could provide much needed future supplements to state and federal revenues for transportation projects if those funds should be reduced.

Many human factors issues exist, such as the need to create incentives for individuals to change to alternate modes of transportation, altering a familiar route, or changing to

other travel times. Public perceptions of the changes brought about by ATMS must also be considered. The credibility of ATMS must be preserved because the general public will not support a poorly maintained or poorly operated traffic management system. Finally, the requirements of the 1990 Clean Air Act could be an important issue in determining how quickly ATMS implementation becomes a reality and in redefining some of the government's own parameters for clean air compliance.

Ultimately, ATMS seeks to give the traveling public what they want most -- a safe, cost-effective transportation system with a high level of personal mobility. Despite the inevitable opposition by some to the changes brought about by new technology, the benefits to Texas travelers should far outweigh any disadvantages.

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INTRODUCTION

With the continued increase in state population, concentrated primarily in the metropolitan areas, has come an increase in traffic congestion on urban Texas roadways. The traditional Texas approach to increase capacity has been to construct more roadways or widen the existing facilities. In the large urban centers, where property values are high, acquiring the additional right-of-way for roadway expansion has become more expensive and difficult. As a result, other options to relieving traffic congestion have been examined. The most attractive solution is the operational approach of enhancing capacity through better traffic management.

Technological advances in computers, electronics and information systems have found an application in Advanced Traffic Management Systems. These systems are being implemented, along with advanced management strategies, on the heavily traveled urban roadways of Texas. The specific transportation-related technologies, management techniques, and the important issues surrounding them are discussed at length in this paper.

The subject of Advanced Traffic Management Systems is broad, so an attempt to narrow it was made by concentrating on ATMS applications in my home state of Texas. This paper discusses ATMS projects in the Houston, Dallas, Fort Worth and San Antonio areas, but this is not to imply that these are the only four cities in Texas where advanced management systems are being implemented. Complete ATMS programs not only involve the effective traffic operations of freeways, but also arterials and frontage roads.

The objectives of this research paper are to indicate some changes expected on Texas roadways as a result of the implementation of new technologies; to provide a historical perspective to advanced traffic management research and implementation in Texas; to present some thoughts that researchers have as to where the future of these technologies is headed; and to address key issues for successful implementation of Advanced Traffic Management Systems.

ADVANCED TRAFFIC MANAGEMENT SYSTEMS

Definition and Goals of Advanced Traffic Management Systems

The concept of managing traffic is as old as traffic itself. Traffic management is simply the administration of a transportation system in such a way as to get the most effective use from the existing network. It extends beyond merely providing the roadway and maintaining it, but involves the smooth day-to-day operations the traveling public demands. As modes of travel became faster and more sophisticated, as population densities increased and as traffic volumes soared, the problems of effective traffic management became more and more complex.

Today, through the application of new technologies, there is the possibility for considerable improvement in the mobility and safety of the traveling public using the transportation network. Advanced Traffic Management Systems (ATMS) rely heavily on state-of-the-art computer technology and the latest innovations in electronics and communications to manage traffic. Information about traffic volumes and incidents can now be collected almost as they occur (known as real-time information), assimilated and intelligent responses generated rapidly and effectively by traffic managers.

Advanced Traffic Management Systems extend beyond technological gadgetry to include management strategies that help alleviate urban traffic congestion. Advanced traffic management strategies include ways to increase user choice and implement demand management. For example, one way to provide greater selection of transportation mode is to improve the efficiency of city bus operations through the use of exclusive busways (sometimes called transitways). Demand management techniques focus on diverting traffic away from congested routes or shifting the travel times and modes at minimal cost and inconvenience. (1) Examples of demand management are high occupancy vehicle (HOV) lanes, company carpooling, flextime work schedules and going to a four-day work week.

Advanced Traffic Management Systems and their application as a management tool have been around in the U.S. since the 1960s. The early concepts of incident detection and management are still around today, but are greatly improved and more cost-effective due to the latest technological advances. Examples of ATMS activities commonly used in freeway management are (2)

- Roving tow or service vehicles,
- Motorist aid call boxes,
- Radios broadcasting traffic reports,
- Incident management "teams",
- Highway and ramp traffic detectors that monitor volumes,
- Ramp metering,
- Motorist information systems,

- Traffic diversion,
- Alternate route identification,
- Closed circuit television surveillance, and
- Central computer control.

The forerunner to IVHS America, Mobility 2000, was an informal group which coordinated U.S. research activities relating to advanced technologies to meet the future transportation needs. (2) In 1989, they identified two primary goals of an ATMS program (3):

1. To apply new technology and control strategies and implement state-of-the-art traffic management systems.
2. To continue to advance the state-of-the-art and enhance technology through research, development, testing and evaluation programs.

Ultimately, the primary objective of traffic operations is to keep traffic flowing smoothly. (4) While it is true that transportation systems must be constructed and maintained, increasing traffic congestion requires that these systems be operated more efficiently. ATMS is one method by which to achieve greater mobility and safety (5). The contributions of ATMS which reduce inefficiencies and improve traveler safety will arise through the influence on trip generation, route selection and greater choice of travel mode.

ATMS, then, is multi-faceted. It is new technologies that amplify operations; it is new management techniques that spread peak periods of traffic and increase the number of occupants per vehicle; it is information systems interfacing with a central control, allowing travelers to make the best decisions about routes, times and modes of travel; and it is an active management tool enabling authorities to operate transportation facilities more efficiently. (1) A well-designed ATMS system merges all these components together into a coordinated system to improve safety and mobility.

Intelligent Vehicle Highway Systems - The Big Picture

Advanced Traffic Management Systems are one of five generic elements that compose advanced transportation operations, commonly referred to as Intelligent Vehicle Highway Systems (IVHS). The others are Advanced Traveler Information Systems (ATIS), Advanced Vehicle Control Systems (AVCS), Commercial Vehicle Operations (CVO) and Advanced Public Transportation Systems (APTS). (2)

These five elements of IVHS are not, however, independent. It is important to understand each of these components because they are an interconnected package, working together. A brief description of each follows.

Advanced Traveler Information Systems

ATIS focuses on communications and guidance. On-board driver information and navigation systems are being developed that display maps, identify alternate routes and update traffic conditions. Other features include pre-trip electronic planning and safety warning systems. (3)

Advanced Vehicle Control Systems

AVCS concentrates on enhancing vehicle control and driver assistance. Such systems may either be roadway-based or vehicle-based. (3) The 1950s idea of burying cables in freeways to automatically zoom cars along while the driver plays solitaire has been replaced by new technologies. (7) The notion of self-driven vehicles is still the basic idea, however, and technology now being developed and tested may make this more feasible in the future.

Commercial Vehicle Operations

CVO is of particular interest to the trucking industry. Fleet management, automatic debiting and weigh-in-motion systems are helping regulators and operators keep up with the movement of goods. (3) The bottom line is cutting operating costs, and these systems, when implemented, should accomplish that purpose.

Advanced Public Transportation Systems

APTS is the newest recognized element of IVHS. Public transit modes such as buses, light rail and high speed rail can play an important part in a transportation network. Some of the real possibilities for IVHS include (1):

- Smart traffic signals that genuinely maximize the efficiency of roads, reducing stops and delays;
- Driver information systems that display congestion information and assist the driver in selecting the best route;
- Systems to provide travelers with reliable transit and rideshare information (e.g., locations and arrival times);
- On-board navigation systems that inform drivers of their location when traveling in unfamiliar areas and guide them to their destinations;
- Systems to warn drivers of potential rear-end, sideswipe, or head-on collisions before they occur so the driver can take corrective action;
- Devices to sense lapses in driver performance and assist in the driving task (e.g., a cruise control device that responds to changes in speed and distance of vehicles ahead);

- Systems to help emergency and transit services dispatch their vehicles as quickly as possible; and

- Systems to improve the efficiency of truck operations which will reduce paperwork and delays.

It is little wonder that, with all this potential for transportation applications, some experts believe IVHS will be as much a boon to mobility and safety in the 21st Century as the Interstate Highway program was in this century. (8)

The Public Benefits of Advanced Traffic Management Systems

In almost everything consumed, price is the indicator by which benefits are measured. Consumers know in advance what they must pay and what they are getting for their money. But in transportation, travel decisions are based, not only on price, but on travel time. Travel comes at a very high price in terms of lost time, accidents, air and noise pollution, inconvenience and missed work.

Since travel times and conditions are often unpredictable, travelers frequently make poor choices in transportation consumption. A better information environment, which Advanced Traffic Management Systems embrace, should change public awareness of travel choices. Intelligent transportation systems should increase the informed nature of decisions that travelers will make. ATMS allows individuals to make necessary adjustments as to whether or not to travel, which travel routes and modes to take, destinations, and when to travel (1). A brief discussion of some specific benefits produced by Advanced Traffic Management Systems follows.

Ramp Metering

A survey for the Federal Highway Administration of seven ramp metering systems in the United States and Canada revealed that average highway speeds increased by 29 percent after installing ramp metering. When delays on ramps were included, average speeds still increased 20 percent and travel times decreased 16.5 percent. Reductions in accidents of up to 58 percent have been achieved by improving merging operations onto highways. (2)

Incident Detection and Management Systems

A 1986 Federal Highway Administration study revealed that the use of a freeway incident detection and management system could reduce congestion on approximately 30 percent of major urban area freeway mileage. The benefit-to-cost ratio returned for this reduction is 4:1. Benefits are measured as the accumulative value of time saved by motorists. Incident duration can be reduced by an average of ten minutes through the use of a freeway incident detection system. (9)

In California, where incidents were monitored by closed-circuit TV and detectors and where incident management teams were dispatched, the average duration of lane blockage was cut in half. (2)

Roving Traffic Patrols

Some of the benefits of roving traffic patrols are (2)

- Motorist sense of security,
- Improved public relations,
- Reduction of requests for police dispatch to incidents, and
- Minimized secondary accident potential.

Changeable Message Signs

There are several beneficial features of changeable message signs (2):

- The reduction of vehicle speeds approaching a traffic queue, which results in fewer secondary accidents;
- Diversion at off-ramps more than a half mile upstream from incidents;
- Lane changes away from blocked lanes are encouraged; and
- Signs upstream from freeway-to-freeway interchanges can be highly efficient.

High Occupancy Vehicle Lanes

Nationwide studies show that high occupancy vehicle (HOV) facilities reduced travel times for users by an average of six percent over the travel times experienced prior to implementation. They also reduced the vehicle miles traveled by approximately five percent. (2) HOV lanes are easily adaptable to use by urban bus systems, which has encouraged greater transit ridership. (10)

RF Radio Communications

RF Radio allows direct communication between the vehicle and the roadside. Traffic information can be targeted so that specific information is supplied when and where it is needed. (6) Audio communications, in general, allow the driver to keep his eyes on the road, which enhances safety.

The specific characteristics of a roadway will dictate which advanced traffic management activities to implement. For example, a freeway with only moderate congestion will probably derive little benefit from high occupancy vehicle lanes or ramp metering. ATMS must be adaptive to changing technology and must respond in real-time to the changing traffic flow. ATMS involves the management of the entire transportation network, including freeways and surface streets, each impacting upon the other.

ATMS must include accurate and reliable surveillance and detection systems and include effective incident management and control strategies. (2) These measures will result in mobility benefits (i.e., reduced delays and increased levels of service) and safety benefits (i.e., fewer accidents, lower property damage, fewer injuries and deaths).

Clearly the use of the conventional measures of traffic management, such as providing more traffic lanes, constructing wider roadway shoulders and the use of good signing, must not be abandoned. Effective traffic management must include an investment in the newest applications of technology while, at the same time, continuing to improve and maintain the existing infrastructure.

THE CONGESTION PROBLEM ON TEXAS ROADWAYS

The Inefficiencies of the Present Infrastructure

At one time Texas emphasized building and maintaining a huge network of roadways. The result was one of the best system of roads in the country, if not the world. The research and development that have been done in the areas of safety, geometric highway design, signing, paving, lighting, etc. have been second to none. But even Texas has boundaries which limit the quantity of roads that can be constructed. (5)

With the increase in traffic volume and urban congestion has come the physical deterioration of existing transportation facilities. Levels of service have declined as evidenced by increased delays, higher delivery costs and more accidents. Finally, there has been a worsening of the air quality in the major metropolitan areas. (11)

According to the Federal Highway Administration, non-commercial vehicles caught in traffic congestion or lost on U.S. roadways cost the country $45.7 billion per year. They further estimated that 2.2 billion gallons of fuel are burned each year by drivers sitting and waiting in traffic. (12)

In Texas, the traffic operations problems of the urban areas can be generally attributed to the steadily increasing traffic volumes rather than poor roadway designs. According to Randy Keir, Traffic Management Engineer for the Texas Department of Transportation (TxDOT), "The growth of traffic is outrunning our ability to keep up by constructing highway lanes. We must manage the use of highways and increase their efficiency." (12) Bob Hodge, Director of Maintenance and Operations for TxDOT, says, "Because we've completed our major construction efforts, the highway network, our job now is to operate them in the most cost-effective manner". (12)

Operational problems are manifested in the form of recurrent and nonrecurrent traffic congestion and congestion due to special events. (13) The nonrecurring congestion contributes most to the problem. Sixty percent of congestion is due to nonrecurring problems (14), random or unpredictable incidents, such as traffic accidents, temporary freeway blockages, maintenance operations or weather-related occurrences.

The most common form of recurring congestion occurs during the peak period when traffic demand exceeds roadway capacity for a short time. Peak period congestion happens daily and is quite predictable. Special events, such as sporting events or parades, are also predictable and often generate large volumes of traffic. (13)

As these problems arise urban mobility is adversely affected. This breakdown in traffic flow results in slower speeds, even stops, and reduced throughput. Despite the fact that 80 percent of nonrecurring incidents are considered minor, quick response to remove these incidents and prevent a breakdown in traffic flow is essential. (14)

Surface transportation users have a choice -- either spend money for increased operating costs, resulting from accidents and delays, or spend money to improve the system. If current levels of funding continue into the future, discounting the effects of inflation, the result could be a $1000 increase in vehicle operating costs per household over the next 30 years. Overall, the nation's mobility will suffer unless more money is invested and funding is increased to improve the surface transportation system. (15) Advanced traffic management facilities will increase the operational efficiency of existing transportation systems, but will go nowhere without strong operating commitment in terms of dollars (16).

Causes of Growth and Congestion in Texas

Since 1950, the total number of registered motor vehicles on Texas highways has increased 351 percent. The increase in the volume of traffic in Texas over the past 40 years can be attributed to several factors: state population growth, affordability of vehicles and gasoline, increase of women in the work force, suburban shifts, increase in the number of households, slow down in new highway construction, movement of jobs into Texas, increase of older drivers and general increase in travel demand.

General Population Growth

The trend in U.S. population shifts over the past 40 years is away from the Northeast and Midwest and into the Georgia-Florida region, the Western states and Texas. Texas ranks third behind California and Florida in the increase of state population from 1950 to 1990 (an increase of 9.3 million people). During this period, the U.S. population increased 64.4 percent while the Texas population increased 120.3 percent.

Most of the state's population increase (8.4 million of the 9.3 million people) has been in the urban areas and formerly undeveloped rural areas surrounding those major urban centers. (3) The metropolitan areas of Dallas-Fort Worth, Houston and San Antonio represent two-thirds of the population increase Texas has experienced over the past 40 years (6.2 million people).

Nationally, over 86 percent of the population growth since 1950 has occurred in suburban areas. (2) In 1950, the urban/suburban population of Texas made up 63 percent of the population. Today the urban/suburban share of the state's population is 78 percent.

Affordability of Automobiles and Gasoline

One reason why there are so many vehicles is the increased affordability of automobiles. In 1960, the median price of a new car by the Big Three automobile manufacturers (Ford, General Motors and Chrysler) was $2900. (17) In 1984, the median price of a new car was $9200. (18) By way of comparison, the average salary for an industrial production worker went from $2.26 per hour in 1960 to $9.18 per hour in 1984. (19) In general, automobile prices tripled over this 24-year period while industry salaries went up four times, making American-made automobiles more affordable to typical industrial workers, and probably to most Americans. When considering the influx of less expensive foreign compacts, this increased affordability may be even more pronounced.

Gasoline prices over the past 40 years have risen at approximately the same rate as salaries, with most of this rise occurring in the late 1970s. In the past decade, the fuel situation in the U.S. has stabilized as gasoline prices have stayed consistently between $1.00 and $1.30 per gallon. American drivers continue to pay considerably less for gasoline than do most of the world's drivers primarily because of a low U.S. gas tax.

The oil market is still soft, and barring any major disturbances in the Middle East, price increases should remain relatively modest in the years ahead. All types of cars have become more fuel efficient, and the supply and price do not appear to be a prohibitive factor in automobile travel -- the travel mode choice of most Americans. (20)

Women in the Work Force

Of the 50 million new workers that entered the U.S. labor force since 1950, 30 million were women. Today, women represent over 45 percent of the nation's labor force. (2) Women are no longer limited to the traditional "women's" jobs such as nurses, teachers and secretaries. The numbers of women in professional and service industries, once dominated by men, are growing. (20)

Well over half the women in the U.S. now work outside the home or are seeking employment, compared with only about a third of women 25 years ago. Nearly two-thirds of married women between the ages of 25 and 44, that are living with their husbands, are in the labor force. With fewer children at home, women have a greater choice of working at either full-time or part-time jobs. In a majority of these cases, women are driving to their place of employment and adding to the peak period traffic congestion.

One result of the women's shift from housework to paid work is that almost half of married couples now enjoy two incomes. This provides two-income families 75 percent more income than the average family in the general population, enhancing their purchasing power and, as a result, gives greater flexibility in where they choose to live. (21)

Suburban Shifts

Approximately two-thirds of all jobs created nationally from 1960 to 1980 were located in suburban areas. The result has been an enormous increase in the number of suburb-to-suburb trips made in metropolitan areas. Of the total growth in commuter trips in the U.S. between 1960 and 1980, suburban commutes accounted for 83 percent. The suburb-to-suburb travel pattern is now twice that of the traditional suburb-to-center city commute pattern in most metropolitan areas. (2)

In 1980, 57 percent of all office space in the U.S. was located in urban centers and 43 percent in the suburbs. By 1986 the situation was virtually reversed; 58 percent of the total office space was in the suburbs and 42 percent in the urban centers. (22)

City Post Oak, in suburban Houston, has 16 million square feet of office space, 3.3 million square feet of retail space and a daytime population of approximately 60,000. Greenway Plaza, also located outside the Houston center city, has 7 million square feet of office space available for rent. The Dallas North Parkway area, in suburban Dallas, has 13 million square feet of office space in place or under construction (another 24 million square feet is planned). The North Parkway area contains three major shopping centers, 11 hotels and six industrial parks. (23)

Suburban-to-suburban travel is almost entirely by automobile since traditional transit services do not serve the lower density dispersed patterns of travel in suburbs very well. Commercial space and employment in the suburbs are growing at much faster rates than they are in central business districts. The result is significantly greater traffic growth in suburban areas where the roadways, originally designed for lower volumes, are now inadequate. (20) Suburban-to-suburban travel also contributes to the number of short trips made on urban freeways, which is a major component of urban traffic volumes.

Another attraction of suburban employment centers is the availability of parking. As opposed to most downtown environments, there tends to be ample parking close to the work areas, and most of the parking is free. (24)

Increase in the Number of Households

There is a direct correlation between the increase in the number of vehicles on the roads and the increase in the number of households. Between 1970 and 1980, 70 million households were created, more than twice the rate of population growth. (2) As the number of households increased, the average household sizes became smaller. The size of an average household is down from 3.4 persons in 1950 to 2.6 persons today. (20) It is the number of households that is important in transportation since travel characteristics tend to be determined more by the household rather than the individual.

A majority of households in the U.S. now have two or more cars and nationally the number of vehicles has surpassed the number of licensed drivers. The number of vehicles per household increased from 0.85 in 1960 to 1.34 in 1980. (2)

Slow Down in New Highway Construction

The Texas transportation infrastructure includes 274,000 centerline miles of maintained streets, roads, and highways, and one million acres of right-of-way. Fourteen million registered vehicles are driven 292 million vehicle miles daily. (25) The Texas Department of Transportation has had their hands full just maintaining and rehabilitating their aging roadway network. (23)

With the Interstate 27 project in Lubbock almost finished, the Interstate Highway System, including its urban segments, is essentially complete in Texas. Most highway construction projects in the state tend to be along short stretches of roadway in a few urban areas or involve the expansion and widening of existing highways.

While the total number of registered vehicles on Texas highways has increased 351 percent since 1950, the total highway mileage over the same period has increased only 38 percent. (25) That comparison is even more lop-sided when measured over the last 20 years. Since the early 1970s, the number of registered vehicles has increased 80 percent compared with a mere five percent increase in highway mileage. (5)

Fortunately for Texas, the highway system that was constructed prior to the slow down in the 1970s had built up considerable excess capacity. This allowed automobile traffic to grow for a while without the system running into serious capacity constraints. Now the slack is just about gone, and most suburban road networks operate close to design capacity. (23) Today, in Dallas-Fort Worth, Houston and San Antonio, the urban freeways are saturated with vehicles regularly, and the result is an increase in traffic congestion, more accidents, and higher levels of motorist frustration. (5)

Movement of Jobs Into Texas

The demographic shifts in population and employment from the industrial states of the Northeast and Midwest to the sunbelt states of the South and Southwest continue. According to the Population Research Service, the Austin metropolitan area was the fastest growing major urban area in the country from 1985 to 1986. Fort Worth was second and Dallas was third. (20)

Texas has traditionally been the home of major employers in the agricultural, petroleum, manufacturing and construction industries. However, as the nature of the job market nationally has changed, Texas has been able to attract many employers in the service and high-tech industries as well. The Texas economy, despite a mild recession in the mid 1980s, currently employs over eight million people. (25)

Houston, with a population of 1.6 million, is the largest city in Texas and the fourth largest city in the nation. The Houston-Galveston-Brazoria metropolitan population is 3.7 million and has a labor force of approximately 1.9 million. Houston is known for it's petrochemical industry, medical and space center, and numerous universities (27 in the greater Houston area). Major industries include equipment manufacturing, petroleum refining, fertilizer, pesticide, agricultural chemicals production, oil and gas pipeline transmission and construction. International interests are represented by 64 foreign bank branches and 54 consular offices. (25) The Port of Houston is the third largest seaport in tonnage in the U.S. (26) The city of Houston has 59 hospitals, and the Texas Medical Center is home to more than 30 hospitals and six medical schools. (25)

The Dallas-Fort Worth Metroplex has a combined population of over 3.9 million. There are ten cities in the Metroplex with populations over 50,000. Dallas is the second largest city in Texas and eighth in the nation. (19) The leading industries in the area are banking, insurance, transportation, manufacturing, data processing and tourism. The nation's largest airport in the area and second busiest to Chicago O'Hare is located between the cities of Dallas and Fort Worth. It contributes to the status of the Metroplex as a transportation hub. The labor force in the entire Dallas-Fort Worth metropolitan area is 1.5 million. (25)

Dallas is a major center of banking, fashion, manufacturing and trade. There are more than 2500 factories in the city, employing 20 percent of the city's work force. Dallas is also one of the world's leading cotton markets. More oil company and insurance headquarters are in Dallas than in any other U.S. city.

Fort Worth's primary industry is manufacturing, which employs approximately 50 percent of the city's work force. The offices of 35 oil companies and 40 insurance companies are located in Fort Worth. The Fort Worth area is home to 1570 industrial plants and is a major Southwest wholesaling center. (26)

The San Antonio metropolitan population is 1.3 million people, ranked third in the state and tenth in the nation. (19) The city's economy depends on tourism, distribution, biotechnology, and a large federal payroll. Five Air Force bases and two Army posts secure defense-related spending. Tourist attractions include the state's perennial number one attraction, The Alamo, several other historic Spanish missions, the Riverwalk, Sea World of Texas, and the recently opened Fiesta Texas. (25) In addition, San Antonio is the chief U.S. manufacturing, wholesale and retail market for Mexico. The labor force of it's metropolitan area is just over a half million. (26)

Increase in Older Drivers

Americans are growing older. According to the 1992 World Almanac, the median age of an American is 32.9, up from 28.0 in 1970. The average American lives 75.4 years today, up from 68.2 years in 1950. (19) There are significantly more people in the category of senior citizens now than there were 40 years ago.

Elderly Americans are generally better off financially today than in previous years due primarily to better pension and social security benefits. They tend to be better educated than past generations and the additional salaries that accompany that education have lead to a better quality of life. Today's senior citizens also tend to be healthier than previous generations. The combination of their good health and greater incomes results in more time for leisure activities. Many are self-employed or choose to work beyond retirement age. All these activities involve travel, usually by automobile. (20)

General Increase in Travel Demand

In 1988, Americans traveled two trillion vehicle miles by automobile, truck, bus and public transit. This was triple the travel mileage of 1956, when the Interstate Highway System was initiated. At current conservative estimates of travel growth of over two percent per year, by the year 2020 total travel in the United States is expected to double again. (15)

Work trips by automobile jumped from 61 percent in 1960 to 82 percent in 1980. (3) According to the Federal Highway Administration, delays on urban freeways are expected to increase 360 percent between 1985 and 2005 in central cities and by 433 percent in the outlying areas. (27)

IMPLEMENTING ADVANCED TRAFFIC MANAGEMENT SYSTEMS

Advanced Traffic Management Systems are not new to Texas or the rest of the country. The Texas Department of Transportation (TxDOT), formerly the Texas Department of Highways and Public Transportation, has long been a leader in traffic management, beginning in the 1960s with the Gulf Freeway System in Houston. Texas has played a major role in the research and development of technologically-advanced freeway management systems and wide-scale implementation is being planned in several areas of the state. (28)

Historical Perspective of Research and Development

Detroit's John C. Lodge Freeway served as the first U.S. freeway system to utilize television surveillance cameras in freeway traffic management. This project was jointly sponsored by 12 states, including Texas, and the experiences and technical knowledge provided helped to lay the groundwork for several early Texas television surveillance projects. (29) The Lodge Freeway surveillance and control system entered planning in 1955 and began operation in 1960. Much of it was rendered inoperable, however, during riots in the late 1960s.

The Eisenhower Expressway, in Chicago, is the oldest continuously functioning surveillance and control system in the U.S. Eisenhower began operation in 1961 and began ramp metering in 1963. (1)

In Texas, studies on the use of television surveillance for the Gulf Freeway (1963) and the Baytown-LaPorte Tunnel (1962) were begun. (29) The Gulf Freeway Surveillance and Control System was initiated in September of 1963 when the Texas Transportation Institute began a research effort to investigate ways of improving the level of service on urban freeways. The research was sponsored by the Texas Highway Department and the U.S. Bureau of Public Roads with the objective of developing criteria for the design and operation of a freeway control system.

Basic freeway characteristics and operations were researched and control theories were formulated. The theories were validated through ramp metering and ramp closure experiments. A full-scale control system of ramp metering signals on eight inbound entrance ramps was established on 3.5 mile section of the Gulf Freeway in the summer of 1965. Early control was done manually by personnel stationed near each entrance ramp.

The first generation of changeable message signs (dynamic message signs) provided information to Texas motorists in the 1960s. Flashers warned of "slow traffic ahead" or "stopped traffic ahead." Special incandescent lights were used to provide the necessary information.

Two prototype ramp controllers were studied and evaluated in 1966. This led to the development of an eight-ramp automatic control system that included 63 loop detectors and a bank of analog devices. This system was installed in late 1967 in a central control center.

A closed-circuit television system was designed and installed in early 1967 to provide visual surveillance of freeway incidents. The system used 14 cameras, spaced at half mile intervals, with 17 monitors in the control center. Each camera could be operated from the control center having pan, tilt, zoom, focus and lens opening remote control functions. A buried cable running 6.5 miles along the freeway provided the transmission for the system.

In August 1967, an IBM 1800 digital computer was installed with the dual capability of freeway control and real-time data acquisition. Studies utilizing the computer as a ramp and freeway system controller were made in 1968 and 1969. This led to an operational control system that became the primary control for the Gulf Freeway. (30)

A deterioration of the freeway infrastructure in Houston and subsequent reduction in their operational efficiency lead officials to begin major reconstruction efforts in the mid 1970s. As a result, the Gulf Freeway Surveillance and Control System was closed down to accommodate the necessary freeway improvements with the idea of re-establishing a similar system once the reconstruction was complete. (31)

The Dallas Corridor Project was a high priority of the City of Dallas and the Texas Highway Department in the early 1970s. The City of Dallas assumed the responsibility for the operation of the freeway control system. The freeway surveillance and Control System, closed-circuit television system, and control center display board became operational in mid 1971. (32)

Like the Gulf Freeway project before it, the Dallas Corridor Project was operationally successful uhntil it was shut down in 1990 to accommodate freeway reconstruction. The North Central Expressway, once completely finished, will include freeway surveillance and control as a part of it's infrastructure. (31)

Texas was among the leaders in the research and development of many Advanced Traffic Management Systems but did not implement on a large scale in the 1970s and 1980s. The support of the state for research and development work on ATMS continued during this period. However, while Chicago and Los Angeles were busy implementing ATMS on a large scale in their freeway systems, Houston and Dallas did not. Texas cities did not commit to wide-scale implementation of ATMS programs for several key reasons:

1. Congestion levels were lower in Texas cities than in many other U.S. cities;
2. Lack of a statewide commitment to operations; and
3. Cost of implementation was perceived as being too high.

The earlier advanced traffic management systems were expensive to implement and had high maintenance costs associated with them. Policy decisions to not implement on a broader scale were made because the benefits of operations produced by these systems did not appear to be very cost-effective with the technology available at the time. Spending highway funds on the construction of more roadways, increasing highway safety and maintenance were higher priorities in Texas at that time. In the decade of the 1970s, Texas continued to expand its freeway infrastructure.

Policy decisions to implement ATMS in other parts of the country were made because the nature and magnitude of the traffic problems were different from those in Texas. Chicago and Los Angeles, for example, had the commitment early on to extensive freeway operations using advanced systems. Chicago historically had a much larger volume of truck traffic, a major contributor to freeway congestion, than either Houston or Dallas. Los Angeles had among the nation's oldest freeways; runaway population growth and serious physical constraints, placed them in dire need of relief. (33)

Since 1979, Texas has been one of the pioneers of exclusive high occupancy vehicle (HOV) facilities, and extensively used park-and-ride lots and transfer centers. The "Reversible Contra-Flow Lanes" in Houston and the "Quick-Change Moveable Barrier System" in Dallas are two innovative solutions to freeway traffic management operating effectively on Texas freeways. The highest volumes of traffic on Houston HOV facilities is now between 1200 and 1500 vehicles per hour during peak periods. Considering that much of this traffic is buses and vanpools, the number of people using the system is very significant. Some of those facilities had to increase their occupancy requirement from 2+ to 3+ because the demand was so high during rush hours. (10)

Integrating New Technology Into the Present Infrastructure

With little or no additional right-of-way available in some highly developed urban corridors, the traditional Texas solutions to increasing capacity by adding new lanes is fast disappearing as an option. (8) The reality is that better use of the present infrastructure must be made, and integrating Advanced Traffic Management Systems can help to accomplish this goal. By implementing ATMS, it is reasonable to expect a one time 15 to 25 percent effective increase in the capacity of a transportation system. The improvements in technology, combined with increasing urban property values, tend to make one-time ATMS implementation more cost-effective overall than periodic lane additions. To not do so is a very ineffective use of resources. (16)

One way to increase the efficiency of the present infrastructure is to apply communications technology to highways. This type of technology should improve the traffic manager's ability to handle peak period traffic, respond to incidents, inform motorists of alternate routes to special events and specify detours around maintenance work. Through the use of road sensors, surveillance cameras and fiber optic cables, communications systems could immediately alert operators of potential problems detected. The operators could then employ changeable message signs, lane control signals or ramp gates to divert traffic as required. If necessary, incident response teams and emergency officials could be dispatched. (12)

Potential travelers, at home or in the office, could access traffic condition information through an information console, personal computer or cable television. Cable television broadcasts, showing areas of congestion on a colored map, would allow motorists to make route decisions before leaving their house or office. Information would be based on real-time data received at the control center. Communications between the vehicle and the traffic control center could be through roadside beacons, wide-area broadcast, or cellular telephones. (1)

Many new technologies are being examined closely and may have possible applications to transportation problems. Video imaging is one promising technology that offers potential for speed enforcement. (6) Video imaging and computer modified images are also being explored as possible ways of enforcing occupancy on HOV facilities. Another application of this new technology is in gaining real-time traffic information to provide comparisons on travel times between HOV facilities and freeway main lanes. (10)

Fiber optics is a rapidly evolving technology capable of handling great quantities of data, video and voice signals. Traditionally the costs have been high, and only systems with the need for very large transmission capacities could justify the expense of a fiber optics system. A traffic surveillance and control system has a relatively low signal demand when compared to the demand of long distance telephone or cable television companies, typical fiber optics users. It is a natural progression to apply fiber optics technology to traffic control systems that consist basically of one-trunk cable systems. (34)

Loop detectors, buried in the roadway and used for measuring traffic volumes, have always been difficult to maintain. Other new technologies are being considered as possible alternatives for real-time traffic data -- video imaging, radar, ultrasonic and infrared devices. They can be placed adjacent to the roadway making them easier to maintain than conventional loop detectors. (6)

On-board information systems, complete with dashboard screens and voice synthesizers so the driver does not have to take his eyes off the road, identify locations of incidents and adjacent vehicles. This could help motorists avoid getting trapped in traffic jams and could reduce collisions. (8) Much of the application currently being developed tends toward specific services requiring on-board navigation (e.g., tourism and delivery). That application is a viable one in some small urban markets. (33)

The Traffic Management Section of TxDOT is currently working to develop hardware and software, standardizing specifications and designs, coordinating research and keeping up with the latest technology. There is incredible potential for the application of new computer technology in the areas of surveillance and response systems. (12)

The Texas Urban Highway Operations Research and Implementation Program is being conducted by the Texas Transportation Institute and the Federal Highway Administration. Initiated in 1989, the five-year project will investigate traffic surveillance, accident detection, traffic control, motorist information systems, coordination of highway design with operations, and the management and analysis of ATMS. Other traffic control techniques to be studied are entrance ramp metering, ramp closures and variable controls for other than main lanes. A new highway operations manual will be compiled that considers operations technology when planning and designing future highways (8).

The Emphasis of Advanced Traffic Management Systems

Advanced traffic management systems have unique characteristics that distinguish them from the management systems of the past (3):

- ATMS works in real-time as current data is provided to the system operators;
- ATMS responds to changes in traffic flow, predicting where congestion will occur and taking steps to prevent it from occurring;
- ATMS includes area surveillance and detection systems;
- ATMS integrates the control of various facilities through the joint management of freeways, arterials and frontage roads and through demand management;
- ATMS includes rapid response incident management strategies.
- ATMS is an unfragmented system, requiring the cooperation and support of a myriad of jurisdictions; and

In addition to these characteristics, there are several possible social, socio-economic and technical approaches that have the potential to reduce traffic congestion or redistribute traffic. Proper implementation and management of these techniques, working in conjunction with surveillance and control, could make a good traffic management system even better. (35) Some possible traffic management techniques follow:

- Staggered or Flexible Work Hours; effects on employee morale and transit operations must be considered.
- Shortened Work Weeks; four day work weeks could reduce congestion on certain days. However, there also may be additional congestion experienced on overlapping days, and workers could replace work trips with nonwork trips.
- Road Pricing; in essence making toll roads out of free roads, discouraging overuse and reducing congestion. Though controversial, it could be used in limited access areas effectively.
- Restricting Access; thru-vehicle traffic eliminated, creating automobile-free zones with facilities for pedestrians.
- Land Use Planning; reduces the potential for congestion by controlling or limiting certain types of development.
- Marketing Strategies; advertising, promotion programs, information systems, fare reductions for transit users, reduced fares for off peak travel, passes, easy payment plans.

- Carpool and Ride Sharing.

- Telecommunications; home and neighborhood work centers equipped with audio, video, facsimile printers and computer terminals over which to conduct business across town without having to make a trip.

- Improved Public Transit Operations.

In the area of public policy, ATMS offers solutions in areas where change is most needed. The areas addressed here are energy, infrastructure, productivity, personal mobility, government and technology.

- Energy. ATMS provides a more efficient highway system, resulting in less fuel consumption by automobiles due to the reduction in stops and delays. Tailpipe emissions could be greatly reduced as a direct result of increased highway efficiency.

- Infrastructure. By closer monitoring of the highway system, the maintenance, rehabilitation and expansion of existing highways could be more accurately assessed.

- Productivity. The improved efficiency of a transportation system contributes greatly to the overall ability to move people and goods. In turn, the additional revenues brought about by greater efficiency could be reinvested to improve the transportation system.

- Personal Mobility. ATMS places an emphasis on that part of the transportation system which relies on the automobile's use.

- Government. Few additional regulations and legislation are required since ATMS emphasizes improving an existing system. Federal funding is already in place for states to use on upgrading their highways. The reduction of exhaust emissions (previously described under "Energy") offers a positive response to the requirements of the 1990 Clean Air Act.

- Technology. ATMS provides many practical applications for new research and development, presenting solutions to everyday traffic problems. (36) "Smart cars," equipped with on-board communications, will have the ability to communicate back and forth with operations personnel. It is quite possible that information about a vehicle's performance (e.g., speed, emissions, rpms) could be transmitted through roadside devices to a data collection point to ascertain real-time emissions for a given traffic stream. Adjustments in traffic control strategies could be made to raise or lower certain emissions characteristics. (33)

The future emphasis of Advanced Traffic Management Systems is in communications. Better pictures of traffic conditions, faster responses to incidents, better route selection, more accurate measures of vehicles emissions and vital real-time traffic data can be anticipated. The end result is more efficient traffic operations. (33)

There is no total solution to the transportation problems being faced today. ATMS, to be truly effective, must interact with the highway user. Therefore, effective traffic management requires that effective communications links be established. Systems must be interactive and flexible so as to maximize the use of the state-of-the-art technology. (36) TxDOT's Randy Keir says, "Our immediate goal is to get the traffic management systems working, such that the smart highways will be available to interact with the smart vehicles that are bound to become a reality in the years to come." (12)

Major Texas Advanced Traffic Management Projects

This section attempts to highlight some of the ongoing and proposed ATMS projects being implemented on Houston, Dallas, Fort Worth and San Antonio freeways. All incorporate traffic control, not just on area freeways, but also on arterial streets and frontage roads. Advanced Traffic Management Systems planned in each of these cities include video surveillance, incident management, real-time traffic data and a central control center.

Houston

The state's prototype active traffic management project is a 14.5 mile stretch of Interstate 45. The project includes freeway, frontage road, and high occupancy vehicle (HOV) lane management systems. (38) Currently, the Texas Department of Transportation is developing the software for the system, and the district office is about halfway through the installation of the hardware. (39)

Houston District Traffic Design Engineer, Bill Ezzell, estimates the project will be complete in 1993, but will require continual updating to keep up with the constantly improving technologies. City and transit officials are working with the district on the installation of HOV lanes and freeway management systems.

The Houston District has similar projects scheduled on U.S. 290 and Interstate 10. The projects will implement lane control signals to notify motorists of closed lanes, ramp meters to regulate intervals between cars entering the freeway, inductive loops to detect traffic incidents, and video surveillance and changeable message signs to inform motorists. (38)

Planning on a state-of-the-art traffic and control system for the Houston freeway system is underway. The $550 million system is expected to be complete in 2010 (8). Houston is developing a contract with an architectural firm to design a building to house the traffic control center. There is a commitment to begin building the facility in the next year and a half to two years. (33) The property has already been chosen for the control center, and plans for clearing the site are underway; right-of-way acquisition and mitigation are currently being settled. (39)

The metropolitan transit authority, METRO, in cooperation with TxDOT, has developed the concept of building single reversible lanes in the medians of freeways to provide an express lane inbound in the mornings and outbound in the afternoons for authorized vehicles, namely buses and vanpools. These lanes were given the name "Authorized Vehicle Lanes" (AVLs). To facilitate safe operations of the reversible AVLs, it was decided to implement surveillance, communications and control systems. The communications media that was selected had to accommodate digital data, voice communications and video transmissions. The decision was made to design and implement a fiber optic cable based communications system. (34)

An extensive plan for HOV lanes and AVLs is being developed for the Houston area. The exclusive HOV facilities operating on the Katy Freeway (Interstate 10) and the North Freeway (Interstate 45) currently move 3500 to 4000 people during the peak hour. The system of HOV lanes and AVLs being developed could eventually push the number of people utilizing the freeway system to between 7000 and 10,000 persons in a peak hour. (40) The long range comprehensive mobility plan calls for 95.5 miles of HOV lanes and AVLs to serve six freeway corridors. (25)

Dallas

Freeway surveillance and control systems will be installed on 17 Dallas area freeways as they are reconstructed. (38) HOV projects are either underway or planned for the East R.L. Thornton, Stemmons and LBJ Freeways and the North Central Expressway. (40)

The Dallas Area Rapid Transit Authority (DART) is currently working on the construction of three transit centers for additional park-and-ride services. (25) The facilities proposed on the North Central Expressway are being coordinated with DART. (41)

Officials in the Dallas District created a Traffic Management Residency which works with a motorist assist patrol and a mobility coalition. The cities of Dallas, Mesquite, Grand Prairie, Irving, Garland, Farmers Branch, Carrollton, Richardson and Plano are represented in the coalition. (38)

Fort Worth

The Fort Worth District is planning a traffic surveillance and control system similar to Houston's system. Their freeway control system will be installed during the reconstruction phases of Interstate 35, already underway, and Interstate 20. If the projects stay on schedule, the district estimates the system will be operational by 2007. (38) The traffic control center, for both freeway and arterial traffic management, will be located in the existing City of Fort Worth traffic control center. (37)

Main lane controls are already operating in Fort Worth showing green arrows over open lanes and red X's over closed lanes. A motorist who sees a red X in his lane knows that there is an accident, breakdown or other obstacle ahead and can change lanes well in advance. This helps to prevent traffic from stacking up in the blocked lane. (8)

San Antonio

The San Antonio District, which was the first in the state to use courtesy patrols, is also keeping up with the benefits of traffic management systems. (38) According to District Traffic Engineer Pat Irwin, a central traffic control center will initially control 28.6 miles of downtown freeway. That project is scheduled to get underway in late 1992.

The long term plan (10 years) is for a 190 mile full access control ATMS system which utilizes state-of-the-art technology. (42) The San Antonio system will incorporate digital fiber optic communications and emphasize incident management. It will use sophisticated video surveillance and detectors to confirm and manage freeway incidents. (6)

Via, San Antonio's metropolitan transit authority, has successfully operated a park-and-ride program in the metropolitan area since the 1970s. VIA's transit buses currently use an Automatic Vehicle Identification (AVI) System, one of the first of its kind in the country. Finally, HOV facilities, not traditionally used in San Antonio, will be accommodated on the most congested portions of Interstate 10 and Loop 410 upon widening. (42)

IMPORTANT ISSUES TO CONSIDER

Any discussion about the implementation of Advanced Traffic Management Systems must include consideration for the social issues involved. The need for a high level of personal mobility is considered a right by most Americans. The automobile's dominating influence on everyday life may be criticized by some, but is generally recognized as providing the level of personal mobility desired by travelers. Planning for transportation systems and the management of those systems must take into account the degree to which life style, personal habits, public policy and community development are currently structured around the use of the automobile. (36)

Coordination Required Among Transportation Entities

Urban mobility, to a large extent, depends upon the effective utilization of urban freeways and surface streets. (13) Because the transportation network extends beyond city limits, county lines and political jurisdictions, maintaining an unfragmented system requires the cooperation and support of many areawide agencies. (3)

Advanced Traffic Management Systems in Texas will require cooperation among transit authorities, cities, counties and TxDOT. (12) For example, in Houston, METRO, city and TxDOT personnel will work together in the operations of the Houston control center. Each agency will be able to dispatch incident response teams. (38) The planning, developing, construction and operation of HOV facilities in Dallas and Houston was done through a joint arrangement between transit agencies and TxDOT. These working arrangements and inter-agency agreements must and are expected to continue. (10)

ATMS must provide for an interconnection of its components in the adjacent communities. (2) The ultimate system would be a comprehensive areawide system that covered all of the freeways, frontage roads and arterial streets, requiring the complete cooperation of every agency in the area. (3) Effective systems, whether comprehensive or not, will cross over several jurisdictions, each having its own agenda.

The Role of the Private Sector

Private sector investment in highway-related research has diminished somewhat in recent years. It has been generally directed toward the development of new construction equipment, materials and scientific instrumentation. (11) With a shift from a transportation program based on construction to one based on operations comes a new structure of organization and management. Much closer public and private sector cooperation is necessary to effectively develop and operate ATMS. (1) Any future research strategy must include meaningful involvement by the private sector. (11)

The Texas Department of Transportation (TxDOT) is interested in what the potential role for the private sector could be in the future operations of ATMS. Historically, the Texas approach has been that state and local agencies are responsible for planning, building, operating and maintaining the roads. Possible arrangements between the public and private sectors are being explored to deal with the changing technological nature of traffic operations. (10)

An in-house design approach, by several TxDOT districts, will keep much of the operation, field inspection, testing and maintenance of the surveillance and control systems in the hands of public sector agencies. Private sector groups, however, could work closely with agency personnel (e.g., in a traffic control center, as emergency technicians, real-time data collection and dissemination, or as part of an incident management team). (38) State and local administrators should be willing to consider the possibilities for new private sector roles in the operation of roads and other transportation systems. This would require some reordering of responsibilities for operations within their respective agencies. TxDOT employees, state, county and local police, city transportation and transit authorities and private sector groups should all have important functions within the advanced transportation networks.

Staffing the traffic management centers will require an ongoing public commitment. Private sector groups may be able to provide some help in that area, much like what is being done in the air traffic control business. The private sector will most certainly be able to bring a level of expertise in the areas of communications and electronics that may be absent in public agencies. Government has had difficulty competing with the private sector in the hiring and the retaining of skilled labor for high-demand technical jobs. Responding quickly to changing labor needs has also been difficult. (1)

Advanced Traffic Management Systems are attractive primarily because they enhance the mobility of travelers. This is what sells the system to the general public that ultimately pays for the traffic management systems. However, if ATMS can provide additional job opportunities that help to improve local economies along the way, that is just an added benefit.

Paying for Advanced Traffic Management Systems

An annual national investment in highways and roads over the next 30 years of approximately $100 billion will be necessary to maintain the existing level of service and to accommodate the necessary improvements for future needs. At about $400 per year per vehicle, road costs represent 10 percent of total vehicle-related expenditures. (15)

TxDOT has identified $412 million in traffic management systems required in Texas's six largest cities over the next ten years. In addition, the department is spending $700,000 per year for research on traffic management issues. (12)

As their tax bases grew and state and federal assistance became more plentiful, local governments came to rely less and less on direct private contributions for infrastructure construction. However, lately there have been economic trends that may soon require consideration for subsidizing transportation-related improvements through other funding sources.

Government funding for transportation could eventually be part of federal budget cutbacks. With greater public pressure to have a more streamlined and fiscally-sound government, reducing the nation's budget deficit has become a major political issue. Gasoline taxes have been raised in Texas from 5 cents per gallon (1984) to the present 15 cents per gallon to create more state revenue. The state lottery was introduced recently for the same purpose. However, as technology continues to make vehicles more fuel efficient and the novelty of the lottery passes, state revenues from these sources could drop. The citizens of Texas have long opposed a state income tax and have historically resisted any tax increases.

Financing of a transportation system that incorporates the suburban traveler has become more expensive as cities continue to move farther away from the urban center. The problems associated with suburban-to-suburban travel have already been addressed. Increased roadway congestion in the outlying areas and the dispersed nature of trips contribute to higher costs of providing an adequate urban transportation infrastructure. (43)

Some of the possibilities for the privatization of financing for specific transportation needs, including ATMS, follow:

- *Negotiated Agreements*; local governments can require developers of projects that are identified through traffic impact analysis as creating major traffic problems to make significant private contributions to transportation facilities.

- *Impact Fees*; "fair share" payments are made by developers based on the number of trips that the proposed development is projected to generate. This applies to the financing of any new or expanded public facilities.

- *Special Taxing Districts*; assessments are collected from property owners within specified boundaries based on property values. They are used to fund infrastructure projects that will directly benefit that particular district.

- *Joint Venture Arrangements*; one or more developers finance a transportation improvement in conjunction with local or state funding.

- *Tax Increment Financing*; legislative allocation of a portion of existing taxes on new development to a transportation fund. It provides a dedicated revenue source instead of relying on budgeted funds. (43)

- *Toll Financing*; could become an essential part of state highway programs, making possible the early completion of projects that might otherwise be delayed. (23)

There are several examples of private funding for transportation projects already underway in Texas. At the North Parkway Center, a 4755 acre complex in North Dallas, impact fees of 50 cents per square foot are helping finance areawide roadway and traffic improvements. In addition, a 5 cents per square foot fee is assessed to support establishment and operation of an areawide Transportation Management Association.

Landowners are allowed to form private taxing districts, called "road utility districts." Highway construction is financed with tax exempt bonds backed by property taxes within the particular road utility district.

Most new toll roads now being planned are essentially commuter highways. This is the case with the Hardy Toll Road in Houston and the Dallas North Tollway extension (23).

The planned Westside Freeway (State Highway 151 near Sea World of Texas) in San Antonio will include local developer and City of San Antonio funding of $13 million for 460 acres of right-of-way and $6 million for frontage road construction. The remaining $68 million for construction of frontage roads, interchanges and freeway lanes in the 10 mile corridor will come from TxDOT. A developer with property in the vicinity of the proposed freeway location agreed to pay a sizeable portion of the project, sensing the opportunity to increase the value of his property. This is a good example of public and private interests cooperating to fund a necessary transportation project. (43)

Private funding sources represent an important supplement to the essential direct public investment in an effort to improve traveler mobility. This could include private sector ownership and operation of transit services on freeways. Privatization of transportation funding allows shifting of some investment requirement away from the public domain and to the private sector. (15)

Human Factors

Demand management is a strategy used by public agencies to encourage individuals to change their travel habits, which reduces the overall demand made on the system. Possible demand management methods to consider are the offering of incentives for rideshare or transit use, spreading peak travel through staggered work schedules or flexible work hours and providing good alternatives to the use of single-occupant vehicles. (23)

Incentives must be given for people to voluntarily change from single-occupant vehicles to car pools, van pools, buses or other means of transit. Two incentives to get individuals to switch modes are travel time savings and more reliability. The combination of HOV lanes with a high quality transit service has proved to be an attractive alternative for people who have the option of taking single-occupant vehicles to change to multi-ridership or public transit modes. (10)

Individuals take many actions in response to congestion or other travel costs. Shifting time of travel to off-peak hours, shifting to a carpool or transit, deferring a trip or changing the route of travel may serve to reduce the total demand for some facilities. (15) Employers and developers are probably in a better position to influence the individual commuter's habits than are public agencies. Employers can set aside preferential parking for carpools and vanpools, provide subsidies to employees that use transit or rideshare, institute variable work hours, sponsor shuttle buses to transit stops, or charge employees and tenants for parking.

In Dallas, the Atlantic Richfield Company (ARCO) operates a subscription bus service for its employees. Twelve routes link nine suburban park-and-ride lots with ARCO headquarters in downtown Dallas. The routes have one or two stops at their origin in the morning and operate express inbound. Employees make a single monthly payment for a guaranteed seat. Surveys are made twice a year to determine interest in new routes. If 25 people make a commitment by signing payroll deduction forms, a new bus is started. On the other hand, if daily ridership on a bus consistently falls below 20, that run is considered for elimination. (23)

Public perceptions must not be overlooked when implementing traffic management strategies. When the first HOV lane was opened in Houston, the vehicle occupancy required to use the facility was 4+ persons. Soon this requirement was reduced to 3+ persons. It appeared to motorists like the lanes were not being used efficiently when, in fact, the criteria used to determine HOV lane efficiency, numbers of people moved, showed this was not the case. The political pressure, however, so great that the facility administrators were forced to drop the occupancy requirement down to the present 2+ persons to give the appearance to the general public of effective lane utilization. (33)

Negative public perception can also hurt a project, as was the case in Detroit in the late 1960s. Some citizens of Detroit expressed their displeasure with ramp metering on the John Lodge Freeway project. They perceived ramp metering as benefiting the suburban commuters to the detriment of the downtown Detroit citizens. The end result was public outrage that actually turned violent. (44)

Another human factors problem to consider is an individual's stubborn resistance to change. For example, in California motorists on a particular stretch of freeway were warned that congested freeway conditions were ahead. The information was relayed clearly and in time for motorists to exit the freeway and avoid traffic congestion by taking an alternate route. However, despite their knowledge of the traffic conditions, uneasiness about getting off a familiar freeway route and possibly driving through undesireable neighborhoods kept many motorists on the freeway. Another attitude observed in California was a motorist's optimism that things could only get better ahead instead of worse. Motorists will not always heed the messages that the traffic managers relay to them. (14)

Motorists not only resist change by ignoring messages, but also through indifference. Surveys were conducted of Houston motorists using the congested mixed-flow freeway lanes and receiving little or no benefit from the HOV lanes. These motorists were asked if they thought HOV lanes were a good transportation improvement. Three out of every four interviewed answered "yes." The public may be supportive of an idea, but not necessarily an active participant. (16)

Meeting the 1990 Clean Air Act Requirements

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) will function as the current vehicle to support expensive Clean Air Act endeavors. ISTEA's $6 billion Congestion Mitigation/Air Quality Improvement Program should perhaps be viewed as Clean Air Act funding. In addition, ISTEA gives the state and local governments more flexibility in determining transportation solutions to their particular problems. They will be given considerable latitude and financial resources to address their air quality and congestion problems.

The guidelines set forth in the Clean Air Act are geared toward helping the nonattainment areas, identified by the Environmental Protection Agency (EPA), to clean up their air. The dangerous components in the air sampled by the EPA are ozone, carbon monoxide and particulates (PM-10). The nonattainment areas in Texas and the degree of the problem identified by the EPA are shown on page 35. (45)

Ozone Nonattainment Areas in Texas:

- "Severe" Houston-Galveston-Brazoria
- "Serious" Beaumont-Port Arthur
  El Paso
- "Moderate" Dallas-Fort Worth

Carbon Monoxide Nonattainment Area in Texas:

- "Moderate" El Paso

PM-10 Nonattainment Area in Texas:

- El Paso

The air quality problem in Texas does not appear to be as serious as in other parts of the country. The nonattainment list for Texas cities is not very long and neither Dallas-Fort Worth's nor Houston's presence on the EPA's nonattainment list is surprising, given their large volumes of traffic and industry.

On the other hand, Beaumont-Port Arthur's and El Paso's air quality problems, as identified by the EPA, may surprise some people. Beaumont is home to an enormous refining and petrochemical complex. El Paso's air quality problem is interesting in that much of the problem is attributed to Juarez, Mexico, a city of a half million people just across the Rio Grande River from El Paso. El Paso, however, contributes to it's own air problem through petroleum refining, smelting, and refining of copper and lead. The Franklin Mountains, to the north of the city, act as a natural barrier to keep many of the air pollutants from drifting away. (26)

The Clean Air Act requires carbon monoxide and PM-10 nonattainment areas to submit a plan for reducing those components which will be reviewed and approved for action by the federal government. The ozone nonattainment areas have specific requirements for immediate action based on the seriousness of the problem.

"Moderate" ozone areas must reduce volatile organic components (VOC) by 15 percent between 1990 and 1996. Emissions due to growth in Vehicle Miles of Travel (VMT) must be offset. "Serious" ozone areas have the same requirements as moderate areas plus an additional requirement of reducing VOC three percent for each three-year period thereafter. "Severe" ozone areas have the same requirements as the serious areas plus implementation of Employer Trip Reduction Programs. These programs require employers with 100 or more employees to increase the average vehicle occupancy of employee work trips by at least 25 percent above the area average.

In addition to the mandates mentioned, the EPA recommends the following transportation control measures be put into action to reduce emissions (45):

- Trip reduction ordinances,
- Limitation of vehicle use,
- Employer-based transportation management,
- Improved public transit,
- Parking management,
- Park-and-ride and fringe parking operations,
- Flexible work schedules,
- Traffic flow improvements,
- Area-wide rideshare incentives,
- High occupancy vehicle facilities,
- Major activity centers,
- Bicycling and pedestrian programs, and
- Voluntary removal of pre-1980 vehicles

Many of the categories the EPA has addressed could be directly or indirectly aided by implementation of Advanced Traffic Management Systems and management techniques previously discussed. However, the federal government's use of Vehicle Miles of Travel (VMT) as a parameter for compliance to Clean Air Act legislation should be flexible.

Effective ATMS implementation will likely produce a high level of service in terms of steady travel by reducing stop-and-go operations. Most experts agree that emissions will probably be less as a result of steady state operations, but until recently there have been no reliable measurements of vehicle emissions to reinforce that theory. If reliable vehicle emissions data confirms that steady state conditions reduce emissions, then some other parameters should be used to achieve compliance with the Clean Air Act.

In steady state traffic conditions there is more VMT during a peak hour. Even if VMT is reduced, congestion during a peak period may not be reduced. It may shorten the length of time of congestion, but not the peak hour volume of traffic. From a practical point of view, trying to control traffic at 70 percent of capacity with traffic management is almost impossible. People are not going to stand for major delays entering a freeway if the freeway appears to be running empty. ATMS, then, could produce smoother operating freeways and help accomplish the EPA's lower emissions goal without necessarily reducing the VMT. (33)

Giving Travelers What They Desire

In a 1985 public opinion survey taken in Houston and Dallas, traffic and mobility were viewed as the major urban problems, ahead of crime and unemployment. Texas travelers are no different from anyone else in the country in that they desire an efficient, safe, cost-effective transportation system that is geared toward their needs. Texans want a high level of mobility that allows them, for example, to make a suburban-to-suburban commute when necessary. (10)

Going back in history to the time when people used horses as the primary mode of transportation, the average commute time individuals were generally willing to tolerate was approximately 30 minutes. That is still true of Texas commuters today, although the distance covered is considerably greater. The better the mobility, the larger the urban area that can be developed and still give people something they are willing to accept.

The improved efficiency of urban freeways after the Interstate Highway System was constructed permitted the population to move farther from the urban center. There is no reason to believe future improvements in the transportation system will not produce similar growth trends. It is quite possible that the inner cities will be hurt by increased freeway efficiency through traffic management systems because the convenience to live a greater distance from the downtown work centers is enhanced. (16)

Another trend that traffic engineers are examining today is the steadily increasing age of the U.S. population. Because getting information to motorists and controlling traffic depends a great deal on visual communication, engineers are creating easier to read letters on signs to help older drivers with poorer eyesight. (46) This is just one example of meeting the changing needs of motorists.

Regarding employer-based traffic management techniques (e.g., staggered work hours), there must be certain considerations made. Employees may find different work hours distasteful, change jobs, demand more pay, or be less productive if forced to adopt other hours. Employers may feel that a change in hours would make their businesses less effective, less profitable or see the whole idea as unworkable. (47)

Offering up any large-scale changes is likely to be unsuccessful, particularly if implementation of the proposal requires changes in institutional structure, economic regulations, more government directives or commitments to large amounts of capital. Small-scale changes are comparatively easier to gain acceptance for and, therefore, should not be difficult to implement.

Several lessons can be learned from examining the Interstate Highway System's successful implementation of new technology. ATMS, like the Interstate system, uses new technology to solve large-scale transportation needs. First, there was a demand by the public for improved personal passenger travel. It gave the public the greater mobility they desired. Second, it applied many innovations that were the next logical step in the evolution of the technology that already existed. Third, practically no institutions or regulations had to be changed. Fourth, there were a large number of winners involved (i.e., the automotive, oil and construction industries). Finally, the benefits were viewed by the vast majority of individuals and groups to far outweigh the disadvantages to a few.

Any technological change is likely to affect some parties negatively, and these parties can be expected to raise their voices in opposition. (36) This was the case with the Interstate Highway System. However, if ATMS can provide the same elements to the urban transportation system that the Interstate Highway System provided, wide-scale implementation will become a reality.

Any transportation system must accomplish three things. It must maintain the quality of life by providing greater choices in where to live, work or participate in desired activities. It must attract growth and bring economic benefits through a reasonable level of mobility. Finally, the system must be credible, which will require continual reinvestments in the infrastructure. There is a proven relationship between a society's level of productivity and the degree to which it makes investments in its infrastructure. (16)

CONCLUSIONS

Advanced Traffic Management Systems (ATMS) extend beyond technology to include traffic management strategies. It is a coordinated system of technology and techniques merging together to alleviate traffic congestion, improve safety and increase mobility.

Any ATMS program should include surveillance and detection systems and an effective incident management and control strategy. Another major component of ATMS is communications. A better information environment increases the informed nature of travel decisions made to avoid congestion. Travelers could make wiser decisions concerning when to travel, what time of day to make the trip, which route to take and whether or not to make the trip.

The traditional solutions of increasing capacity, namely building more roadways and adding lanes, are being replaced by an increased emphasis on better traffic management. Construction and maintenance should not be considered unimportant because of a shift to an operational emphasis. They are still a vital part of a transportation system. There are many benefits to successful implementation of ATMS technology. Among these are a reduction in accidents, an increase in average speeds, less delays, a high benefit-to-cost ratio in terms of time saved, a reduction in travel times, a reduction in incident duration and, ultimately, an increase in the level of service.

Operational inefficiencies are largely attributed to increasing volumes of traffic rather than inherently poor highway designs. The end result is a deterioration of the transportation infrastructure and air quality. Overall the nation's mobility will suffer unless more money is invested to improve the transportation system. ATMS should increase operational efficiency, but needs strong commitment in terms of money and personnel.

ATMS offers attractive solutions to traffic congestion problems through the application of advanced technology. Houston, Dallas, Fort Worth and San Antonio are planning extensive implementation of ATMS. Traffic control centers, reliable real-time data collection, surveillance and incident management systems are planned in all four areas.

The financial contribution by the state and federal government to transportation may shrink as a result of upcoming budget cutbacks. There may be a need for supplementing these funds through private-sector sources.

Incentives may need to be offered to prompt individuals to voluntarily change from their single-occupant vehicles to other modes. Employers are in a better position than the government to influence individual commuter habits.

Public perception of the results of ATMS must not be overlooked because strong public opposition can politically overpower the applications of any new technology. Traffic managers must understand human nature, such as fear of the unfamiliar, resistance to change and apathy. A successful ATMS program must be perceived by the general public to have far greater advantages than disadvantages.

Transportation systems must be safe, cost-effective and increase personal mobility. There also must be a constant reinvestment in the transportation infrastructure.

RECOMMENDATIONS

Based on the research and discussion presented in this paper, the following recommendations are made in regard to successful implementation of Advanced Traffic Management Systems in Texas:

1. The commitment to ATMS in the large cities should include some meaningful involvement by the private sector in conjunction with the public sector. TxDOT should consider the potential expertise that the private sector can offer in the areas of communications and electronics.

2. The Environmental Protection Agency (EPA) should be flexible when using Vehicle Miles of Travel (VMT) as the parameter by which compliance to the 1990 Clean Air Act is measured. ATMS may serve to reduce congestion and vehicle tailpipe emissions while not necessarily reducing VMT.

3. ATMS does little to strengthen the decaying conditions of the inner city. In fact, it works to strengthen suburban residence and workplace tendencies. Municipalities in large Texas cities must renew their commitment to revitalizing their inner core and provide incentives for living and building businesses in those areas.

4. Private sector funding sources need to be used on a broader scale to fund statewide transportation projects. Federal and state funding for transportation could decrease as budget cutbacks become necessary to balance the federal budget deficit under increasing political pressure.

5. Incentives must be offered by large private sector and public sector employers to their employees, in the Houston and Dallas-Fort Worth areas, which will prompt voluntary shifts from single-occupant vehicles.

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