Alternative Transportation Modes Analysis

Part of the Destination 2030
The Long Range Transportation Plan for the Tulsa Region

INCOG
Transportation Planning Division

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1.0 Introduction

The Alternative Transportation Modes Analysis study was prepared by the Indian Nations Council of Governments (INCOG) to address traffic congestion issues in the Tulsa region. With the Tulsa Metropolitan Area population projected to increase from 803,235 to 970,400[1] between 2000 and 2030, it is expected that congestion problems will worsen with the heavy usage of the existing transportation system. The congestion on highways diverts the traffic to alternate, less efficient routes, spreading the adverse impacts to the local streets. Accidents can also be a significant source of congestion. The City of Tulsa reported 10,321 accidents on City Streets in 2001, a 3% increase from the 10,015 accidents in 2000. On Tulsa Highways the total number of accidents was 2,760 in 2001.[2]

The limited use of public transportation and carpooling, and the lack of other transportation alternatives is a fact in the Tulsa region. As part of a multi-modal approach to address the region's transportation needs, the 2025 Transportation Long Range Plan addresses transit improvements, park-and-ride lots, trails and sidewalks. However, lack of funding and public support is the major problem facing transit improvements. According to residents surveyed in 2002, there is a high willingness to invest more in street and highway maintenance and expansion, some willingness to invest in or expand bicycle / pedestrian projects, transit, and technology enhancement. Although great interest in rail exists, there is little willingness to fund it.

Before increasing the capacity of roads and highways, it is necessary to identify viable plans of action that take into account all modes of transportation and the needs of the economically disadvantaged. This study identifies and evaluates transportation policy alternatives and presents developed criteria that determine the strategy that best meets the regional transportation needs.

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[1] Oklahoma Department of Commerce – Population Projections for Counties: 2000 – 2030.

[2] Oklahoma Department of Transportation Accident File 2001.

2.0 Existing Conditions

The Tulsa Transportation Management Area roadway network is characterized as a grid system. It is served by two Interstate highways, I-44 and I-244, and several other routes comprised of US-75, US-169, US-64, US-412, US-51, SH-266, and the Creek Turnpike. Several area expressways connect suburban communities with downtown Tulsa and other major shopping and industrial districts.

The Tulsa area expressway system carries some of the heaviest traffic in the state of Oklahoma. Arterials carry 46% of the vehicles miles of travel (VMT)[3]. Growth in VMT exceeded population growth by a wide margin because of an increase in trips per household. The fast increase in VMT results in a decline in roadway performance, congestion, travel delays, increase in fuel consumption, and poor air quality. *Table 1* displays current and projected traffic volumes for select Tulsa Area expressways.

Table 1

Tulsa Area Expressways: Current Traffic Counts and 2025 Forecast

Expressway Segment	Current Traffic*	2025 Forecast Traffic*
SH-51 Broken Arrow Expressway (21st St to Harvard)	112,400	121,300
US-169 Mingo Valley Expressway (51st St to 61st St)	126,800	146,100
I-244 Crosstown (SH-11 to US-169)	103,100	125,500
I-44 Skelly Drive (Harvard to Yale)	80,900	106,300
SH-51 Broken Arrow Expressway (I-44 to US-169)	91,800	143,800
I-44 East (177th E Ave to 193rd E Ave)	76,200	90,900
US-64 Keystone Expressway (33rd W Ave to CBD)	69,900	75,074
US-75 South (I-44 to 61st St)	48,900	64,800
US-75 North (36th St N to 56th St N)	40,800	81,000

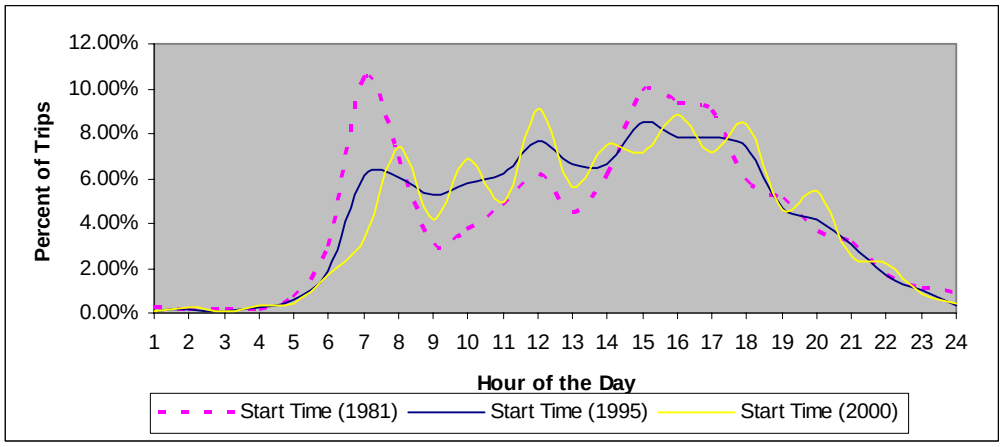
Source: City of Tulsa (*2000/2001 traffic is a weekday traffic count unadjusted for seasonal or other factors) and INCOG (2025 traffic is an average weekday forecast volume of traffic).

Traffic volumes vary according to the day of the week and time of the day. Because offices and schools are closed, weekend traffic volumes are lower. Traffic is minimal during late-night and early-morning hours, but is increasingly being spread

[3] Vehicle Miles of Travel (VMT) is a measure of travel obtained by multiplying the total volume of traffic with the average distance traveled by using an automobile.

throughout the day rather than concentrated in the traditional morning and evening rush hours.

Figure 1



Source: National Personal Transportation Survey (NPTS)

Commuter driving patterns indicate the vast majority of commuters drive alone. In 1980, 72% of drivers in the Tulsa MSA (Metropolitan Statistical Area) drove alone, and that has increased to 80% in 1990 and 81% in 2000. This increase in single-occupancy vehicles comes at the cost of Transit ridership, which is down from 0.92% to 0.7%. Based on Census 2000, mean travel time to work in Tulsa is 21.5 minutes one-way, a growth of 1.8 minutes from 19.7 minutes one-way in 1990.

Historically, passenger rail and trolley services have been used in the Tulsa region, but today service is provided solely by bus. The bus service is operated by the Metropolitan Tulsa Transit Authority (MTTA). Due to funding constraints, service has been reduced several times during the last two years causing ridership to decrease in high proportions. Average ridership is less than 10,000 users daily.

Major obstacles exist in the expansion of alternative modes, the main one being competition with the convenience of the automobile. Vanpools and carpools are minimally used. High Occupancy Vehicles (HOV) lanes do not exist in the region. Pedestrian and Bicycle means account for less than 1% of travel, according to the National Personal Transportation Survey (NPTS) taken in 2000.

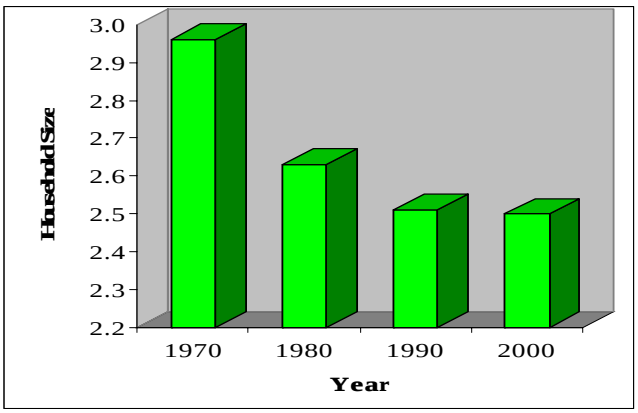
3.0 Future Conditions

It is projected that the population of Tulsa TMA, comprised of Tulsa and parts of Creek, Osage, Rogers, and Wagoner Counties, will grow by 15% to nearly 700,000 people from 2000 to 2025. A 1% average annual growth rate for the TMA between 1995 and 2025 is projected.

Recent population trends indicate that population growth is occurring throughout the Tulsa MSA. Between 1990 and 2000, the City of Broken Arrow accounted for 29% of the region's population growth, and the City of Tulsa accounted for 7%. Rogers County accounted for 28%, and Creek, Osage, and Wagoner counties shared 36% of the balance of the MSA's population growth.

Changes in the composition of households also affect travel behavior. The median age of area residents has increased from 28.8 years in 1970 to 35.1 in 2000. Youth, as a share of the population, are projected to decline, and the elderly population (age 65 and over) is projected to reach 17% in 2020. In addition, the size of typical households has changed dramatically. Population per household for the Tulsa MSA declined from 3 persons in 1970 to approximately 2.5 persons in 2000 and is expected to level off.

Figure 2



*Source: Nationwide Personal Transportation Survey
**Excluding persons in group quarters (such as dormitories, jails, etc.)
Geography: Tulsa MSA

Population growth is anticipated throughout the metropolitan area, specifically south Tulsa, Bixby, and the Broken Arrow corridor as well as the Coweta, Jenks and Owasso areas. Strong long-term employment growth is expected to continue for the Tulsa metropolitan area based on the Bureau of Economic Analysis Forecasts. Employment projections anticipate an average annual growth rate of 1% a year till 2025. Service and retail industries are projected to lead the growth in employment followed by manufacturing, transportation, communications, and utilities. Approximately 94% of the MSA employment falls within the TMA boundary. Employment growth is anticipated throughout the metro area including significant increases at the Cherokee Industrial District, Downtown Tulsa, and the Broken Arrow Expressway Corridor.

In summary, population, households, workers, licensed drivers, and the number of vehicles have all increased significantly while trip lengths in minutes and trip lengths in miles have changed only slightly. Dramatic increases have occurred in the number of vehicle trips made and the total miles traveled. Tulsa drivers are not generally driving further distances per trip but simply making more trips per day, increasing the total number of vehicle miles traveled.

4.0 Identification of Alternatives

The 2025 Long Range Transportation Plan (LRTP), as well as long-range studies and reports developed by INCOG and MTTA, anticipates the need of transit service improvements but doesn't detail the implementation or funding availability for the improvements. The 2025 LRTP addresses the necessity of a dedicated transit funding source, expansion and improvement of the transit system, and enhancement of services. The Plan also encourages promotion of carpool and vanpool services, development of a commuter rail service starting in the Broken Arrow Expressway corridor, and establishment of park-and-ride facilities to provide convenient access to public transit services.

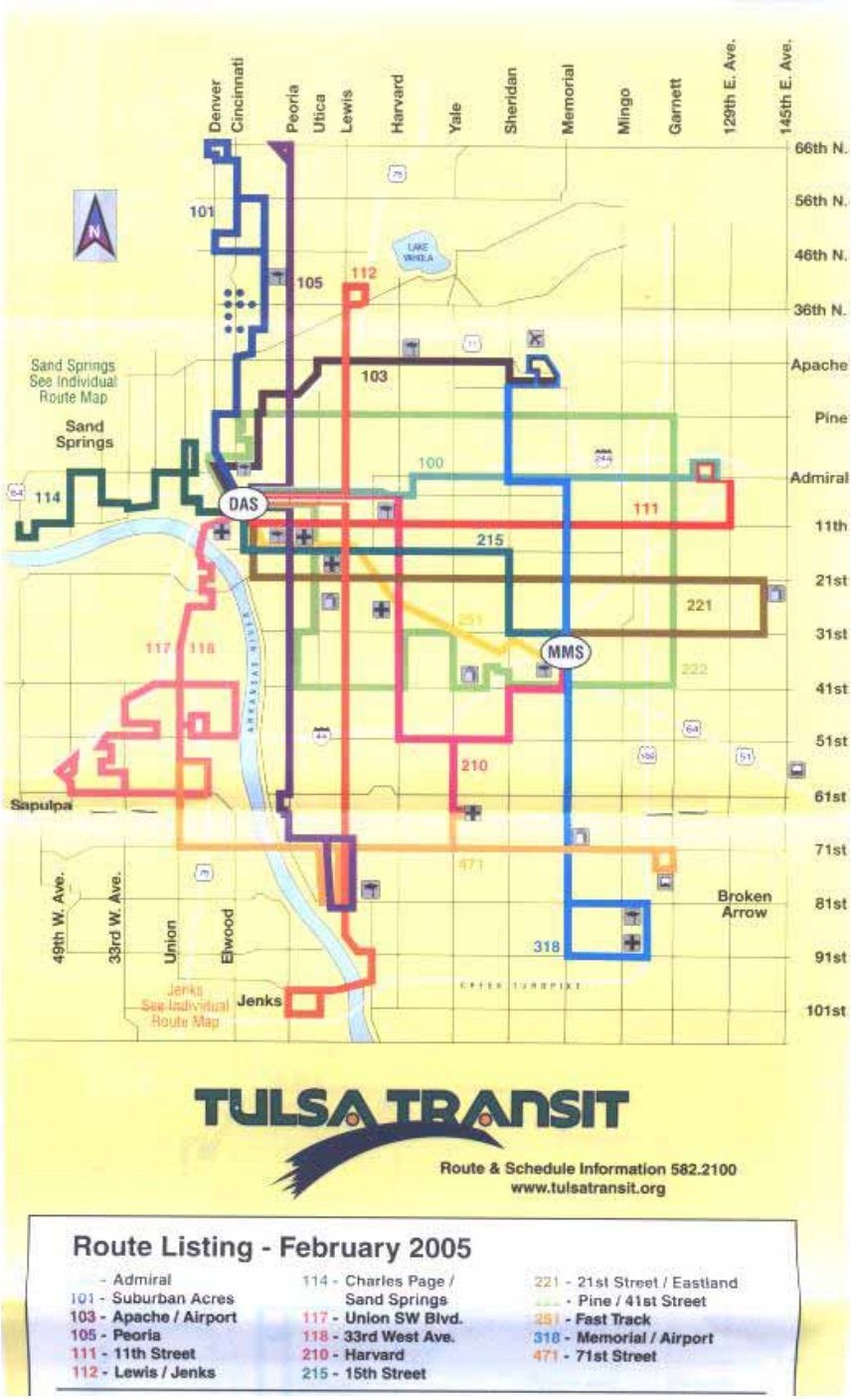
Prospects for implementation of transit improvements are not in the near horizon due to funding availability. However, the projected growth and the significant increase of traffic in the region, described above, will require capacity improvements on the regional transportation system. The absence of capacity improvements on both highways and major arterials will increase congestion, lower travel speeds, increase travel times and cause major delays - especially during traffic accidents. Therefore, in the absence of capacity expansion, alternative modes should be implemented to avoid the negative impacts caused by congestion.

Before analyzing the transportation mode options, it is important to review what is currently being offered to Tulsa area residents. Transit services are provided by MTTA. With a fleet of 60 vehicles, Tulsa Transit offers fixed route and paratransit services primarily for most of City of Tulsa, part of Sand Springs and Jenks. There are approximately 15 fixed routes, four nightline routes, and three express routes being operated only six days a week. Tulsa Transit serves 304 square miles and a population of approximately 474,668.[4]

[4] National Transit Database - 2000

In 2001, ridership totaled 3,114,212. The following year, ridership decreased to 2,810,101. Economic constraints forced a significant reduction in services, and ridership dropped to 2,639,714 in 2003 and to 2,042,182 in 2004.[5]

Figure 3 – Tulsa Transit Fixed Route Service



[5] Data provided by the Metropolitan Tulsa Transit Authority.

Although transit is usually seen as a heavily subsidized mode of transportation, the same could be said for automobile use. The fuel tax provides a mechanism to best internalize automobile-related economic costs, which are currently subsidized.

Figure 4

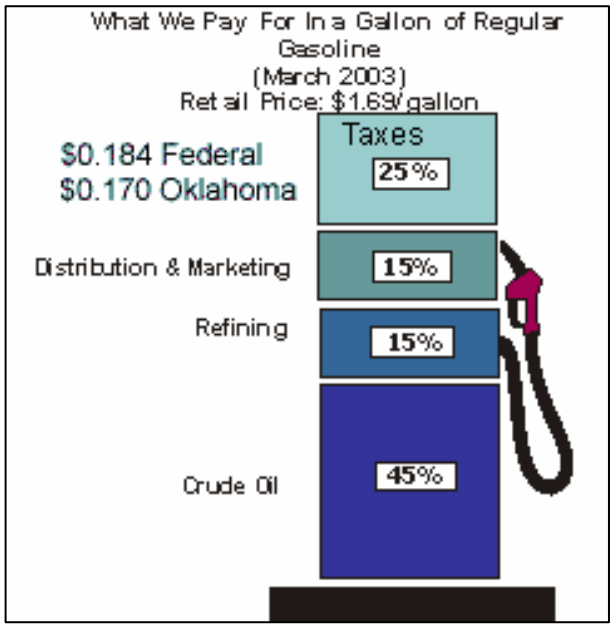


Figure 4 shows the prices paid for gasoline.[6] As can be seen, 75% of the price reflects the market costs of the fuel as a commodity, and only 25% is collected as taxes to pay for infrastructure, right-of-way, environmental degradation, law enforcement, management, planning, and all the other costs to society that are the responsibility of the government.

Infrastructure costs consist of roadway construction and maintenance, right-of-way acquisition, traffic signals, etc. In 2003, Oklahoma budgeted nearly $450 million dollars for transportation projects[7]. Although a large part of infrastructure costs is paid for by the fuel tax and tolls, more and more of it is being supported by bond, which is paid by everyone. However, it is unlikely that people would choose public transportation instead of their personal automobiles unless cities helped implement policies that supported the transit system. Increases in parking costs, gas, and tolls, are just a few examples of external costs that could be implemented by policymakers. The fact that these costs are usually ignored make the full costs of the automobile be underestimated,

[6] A Primer on Gasoline Prices, Energy Information Administration, (http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp)

[7] OKLAHOMA STATEWIDE TRANSPORTATION IMPROVEMENT PROGRAM (STIP) FOR FFY 2003 – 2005, Oklahoma Department of Transportation, pg. 8.

the potential benefits of transit be undervalued, and the benefits that extend to every segment of the population be overlooked.

The enhancement of the Tulsa transportation network and the strategic development of a multi-modal system would not only respond to the needs of the economically disadvantaged, transit dependent population. It would also benefit the overall population by providing affordable, safe and convenient transportation alternatives, reducing congestion, and helping to conserve energy resources and improve air quality.

Public transportation benefits every segment of society. It also helps the nation with its goals and policies. Some of these benefits are[8]:

- Safety and Security: Public transportation is significantly safer when compared to automobiles. According to the National Safety Council, bus passengers are 170 times safer than drivers. "Trips with similar destinations result in 200,000 fewer deaths, injuries and accidents when made by public transit than by car, adding up to between $2 billion and $5 billion per year in safety benefits".
- Reliable Emergency Services: There are various examples around the country where communities were evacuated after natural disasters.
- Environmental Preservation: Annual emissions of the pollutants that create smog are reduced saving between $130 million and $200 million a year in regulatory costs.
- Public Health Improvement: Residents are exposed to fewer diseases caused by air pollution since public transportation produces only a fraction of the emissions of automobiles.
- Energy Conservation: Public transportation reduces dependency on foreign oil.

[8] Data extracted from The Benefits of Public Transportation – An Overview, published by APTA – American Public Transportation Association, September 2002.

- Congestion Relief: It provides choice, taking cars off the road. For example, in Denver, nearly 50% of light rail riders previously used cars. The LRT system in Denver, Salt Lake City, and Dallas attracted 60%, 43%, and 30% more riders, respectively, than projected. It also provides mobility to low-income people, and those who do not have access to cars.
- Connectivity with different modes of transportation.
- Stimulation of the Economy.
- Creation of jobs.

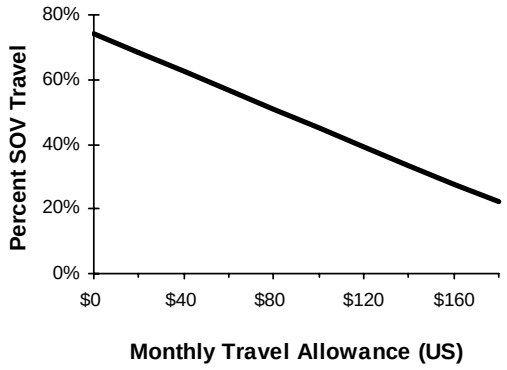
There are innumerous financial incentives that could encourage commuters to shift transportation modes. Some examples are:

- Parking cash-out: money, equivalent to subsidized parking, offered to employees if they use alternative transportation mode.
- Transit fares and rideshare benefits: employers provide free or discounted fares to their employees.
- Parking subsidies: no subsidies for employees who drive to work.
- Tax Incentives: Potential government policies benefiting transit usage.

Figure 5 illustrates the effect economic incentives have on single occupant vehicle (SOV) trips, reducing them significantly depending on the magnitude of the benefits offered:

Figure 5

Effect of Economic Incentives on SOV Rates (Rutherford, 1995)

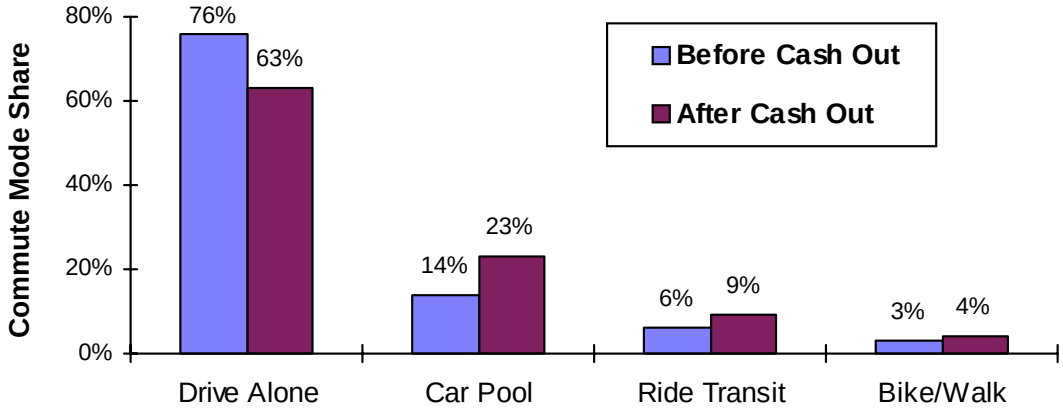


SOV travel decline as economic incentives for other modes increase.

It has been proven that SOV trips have decreased after the implementation of the parking "cash-out" program in worksites at several urban areas.

Figure 6

Cashing Out Impacts on Commute Mode (Shoup, 1997)



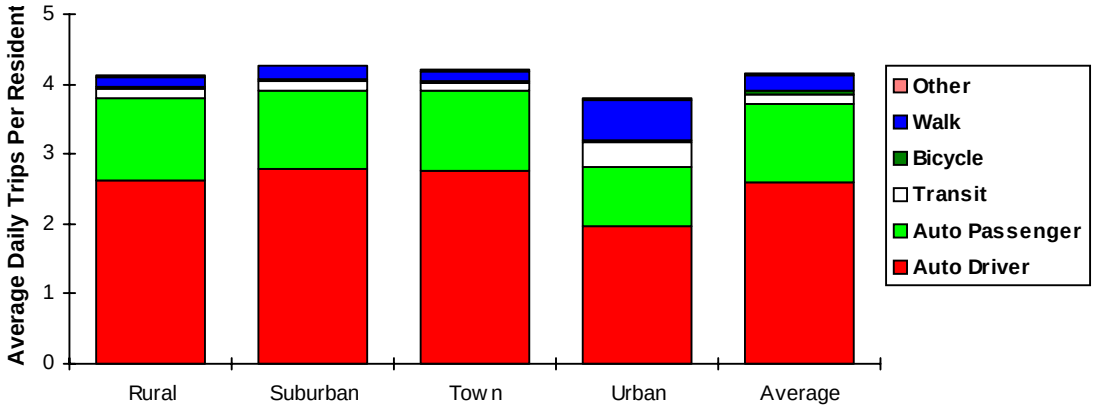
Parking Cash Out results in reduced automobile commuting and increases in carpooling, transit and nonmotorized travel.
Source: Donald C. Shoup - University of California, Los Angeles

Another factor that affects transit demand is service improvements. Increase in headways, improved customer service, convenient transfers, and easy schedules can all positively affect transit ridership. Land use patterns such as accessibility, density, and mixed land-use have influence on travel patterns and mode choices. Because higher density areas tend to increase traffic congestion and reduce speeds, they rely more on

alternative transportations than low density areas. *Figure 7*, derived from the National Transportation Survey database, reinforces the theory that a decrease in automobile use (25% less) is seen in higher density areas when compared to other areas.

Figure 7

Average Daily Trips per Resident by Geographic Area (NPTS, 1995)

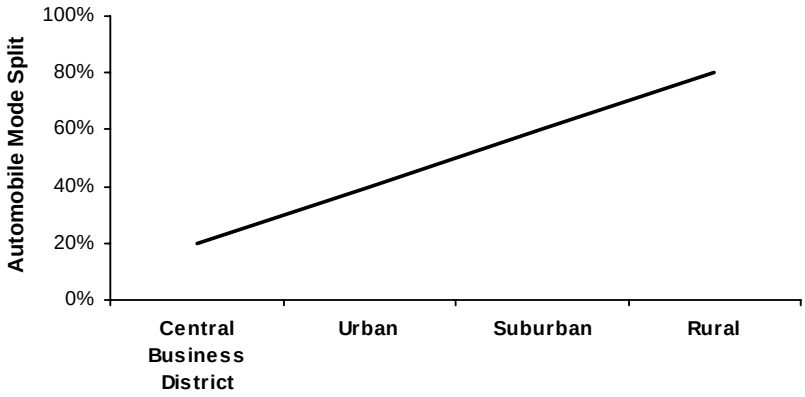


Urban residents drive less and use transit, cycling and walking more than elsewhere.
Source: TDM Encyclopedia - Victoria Transport Policy Institute

Mixed land-use reduces the distance that people need to travel for services. The probability of owning a car decreases and the use of alternative modes increases considerably for residents of Transit Oriented Developments (TOD).

Figure 8

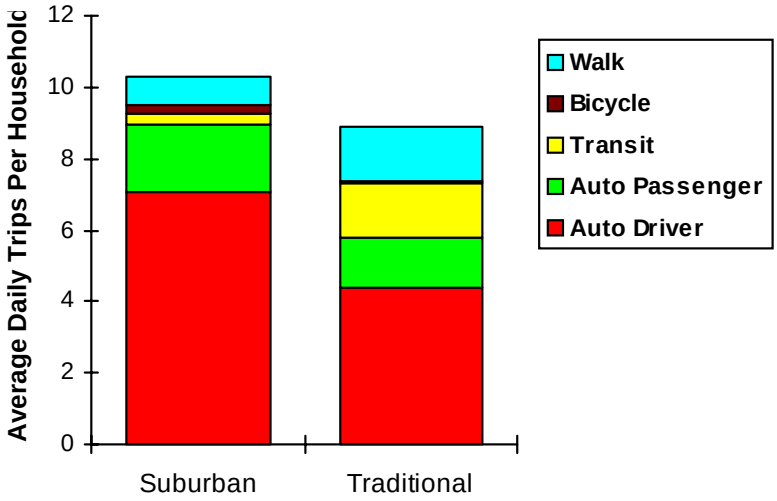
Transportation Impacts of Urbanization



As an area becomes more urban, automobile mode split declines and a greater portion of trips are by walking, cycling and public transit.
Source: TDM Encyclopedia - Victoria Transport Policy Institute

Figure 9

Household Travel by Neighborhood Type (Friedman, Gordon and Peers, 1995)



Vehicle trips per household are significantly higher in automobile dependent suburban communities due to lower densities and fewer travel choices
Source: TDM Encyclopedia - Victoria Transport Policy Institute

Traffic calming, reduction of parking availability, pedestrian-oriented commercial districts, and pedestrian / cycling improvements are also important policy decisions to support mode split.

A list of potentially feasible alternatives for the Tulsa region was developed. However, for the purpose of comparison, it is necessary to analyze the physical and operational characteristics such as capital and operating costs, operating speed, ability to provide congestion relief (mobility), travel time impacts, and ridership (capacity).

List of Alternatives:

1. Bus Service Improvements
2. Bus Rapid Transit (BRT)
3. Light Rail System
4. Commuter Rail System
5. HOV / HOT Lanes
6. Bicycle / Pedestrian Improvements

5.0 Alternative Modes

Transportation modes compete with each other to gain market share. There are several indicators that influence people's mode choices and decision-making in a region. Some factors include:

- Costs and payment options
- Travel time and speed
- Schedules (frequency, availability)
- Comfort, convenience and safety
- Accessibility
- Reliability
- Aesthetics

Cost is one of the most important factors in determining a transportation mode's feasibility. If the cost of the alternative mode is perceived to be higher than the cost of driving then ridership will decline. Besides gasoline, there are several external costs associated with operating an automobile; however, these other costs are not always perceived by consumers and, to remain competitive, transit agencies cannot charge more than what these riders would have spent in gasoline.

Travel time is another important factor that affects mode choice. To attract riders, transit has to provide trips with travel time either equal to or less than the automobile.

Ridership also declines if transit agencies fail to meet users' expectations regarding schedules, comfort, safety, and accessibility. It is necessary to offer a flexible and compatible schedule that can meet riders' needs, avoid transfers, and have transportation as close as possible from origins and destinations.

5.1 Bus Transit Service

Bus is still the predominant mode of transportation, providing the majority of public transportation services to most cities. Even in areas where rail lines exist, buses are necessary to provide service to and from rail stations and also to low-density areas that are not covered by any other transportation system. Services are provided along major or minor arterial streets with headways ranging from 5 to 60 minutes depending on peak hours and ridership.

The vehicles can be:

- Articulated: 55 to 60 foot long vehicles able to carry approximately 90 passengers.

- Traditional: 40 to 45 foot long vehicles able to carry an average of 60 passengers.

- Neighborhood Circulator: 30 foot vehicles used to circulate in neighborhoods and able to carry just a small number of passengers.

- Trolley Bus: vehicles powered by overhead electrical wires.

5.1.1 Capital and Operating Costs:

Capital costs are related to the purchase of rolling stocks (vehicles), facilities (terminals, transfer facilities, shelters, stations) and equipment (furniture, fare collection equipment, automatic vehicle location). The largest item of these costs is related to the acquisition of vehicles.

Table 3

Average New Bus and Trolleybus Costs, 2002-2003, Thousands of Dollars

TYPE OF VEHICLE	BUS	TROLLEYBUS
Articulated (55'-61')	452	813
Intercity (35'-45')	389	NA
45' Transit (45')	460	NA
40' Transit (37'6"-42'5')	295	464
35' Transit (32'6"-37'5")	283	NA
30' Transit (27'6"-32'5")	262	NA
Suburban (35'-45')	288	NA
Trolley replica (all lengths)	248	NA
Small Vehicle (<27'6")	94	NA

Source: American Public Transportation Association survey of 10% of non-rail transit agencies.

Operating costs are associated with the operation of the service, including vehicle operation supplies, vehicle and facility maintenance, agency administration, employee salaries and benefits, materials and supplies, utilities, liability, etc. These costs vary from agency to agency. *Table 4* lists capital and operating expenses from transit agencies serving areas similar to Tulsa:

Table 4

Major Bus and Trolleybus Agency Financial Data, Fiscal year 2001 (Thousands)

PRIMARY CITY SERVED	TRANSIT AGENCY	CAPITAL EXPENSE (000) (b)	FARE REVENUE (000)	OPERATING EXPENSES (000)
Albuquerque, NM	Sun Tran of Albuquerque	7,584.4	3,745.2	17,124.9
Austin, TX	Capital Metropolitan Transportation Authority	34,217.0	3,921.3	69,270.3
Cincinnati, OH	Southwest Ohio Regional Transit Authority	15,479.3	18,817.1	63,036.6
Colorado Springs, CO	Colorado Springs Transit	4,033.6	1,909.8	7,023.8
El Paso, TX	El Paso Mass Transit Department	9,771.5	6,601.8	25,233.1
Fresno, CA	Fresno Area Express	3,970.5	6,416.1	21,927.7
Ft. Worth, TX	Fort Worth Transportation Authority	9,640.3	2,987.9	26,874.6
Kansas City, MO	Kansas City Area Transportation Authority	5,447.4	NA	49,546.3
Knoxville, TN	Knoxville Transportation Authority	3,042.8	1,284.9	7,687.8
Little Rock, AR	Central Arkansas Transit Authority	4,957.2	1,553.4	7,922.1
Long Beach, CA	Long Beach Transit	16,043.4	12,472.4	45,538.8
Louisville, KY	Transit Authority of River City	9,040.5	5,780.2	40,460.1

Memphis, TN	Memphis Area Transit Authority	3,100.2	849.8	31,272.9
Oklahoma City, OK	Central Oklahoma Transit & parking Authority	721.6	3,073.8	11,273.9
Omaha, NE	Omaha Transit Authority	5,233.3	3,634.6	14,198.4
Sacramento, CA	Sacramento Regional Transit District	8,552.8	14,850.6	59,389.2
Toledo, OH	Toledo Area Regional Transit Authority	6,418.1	4,540.9	17,693.9
Tucson, AZ	City of Tucson Transit System	6,770.7	6,710.0	31,099.4
Tulsa, OK	**Tulsa Transit Authority**	**2,287.8**	**1,838.7**	**9,827.1**
Wichita, KS	Wichita Transit	556.4	1,595.8	5,351.4

Source: Federal Transit Administration National Transit Database

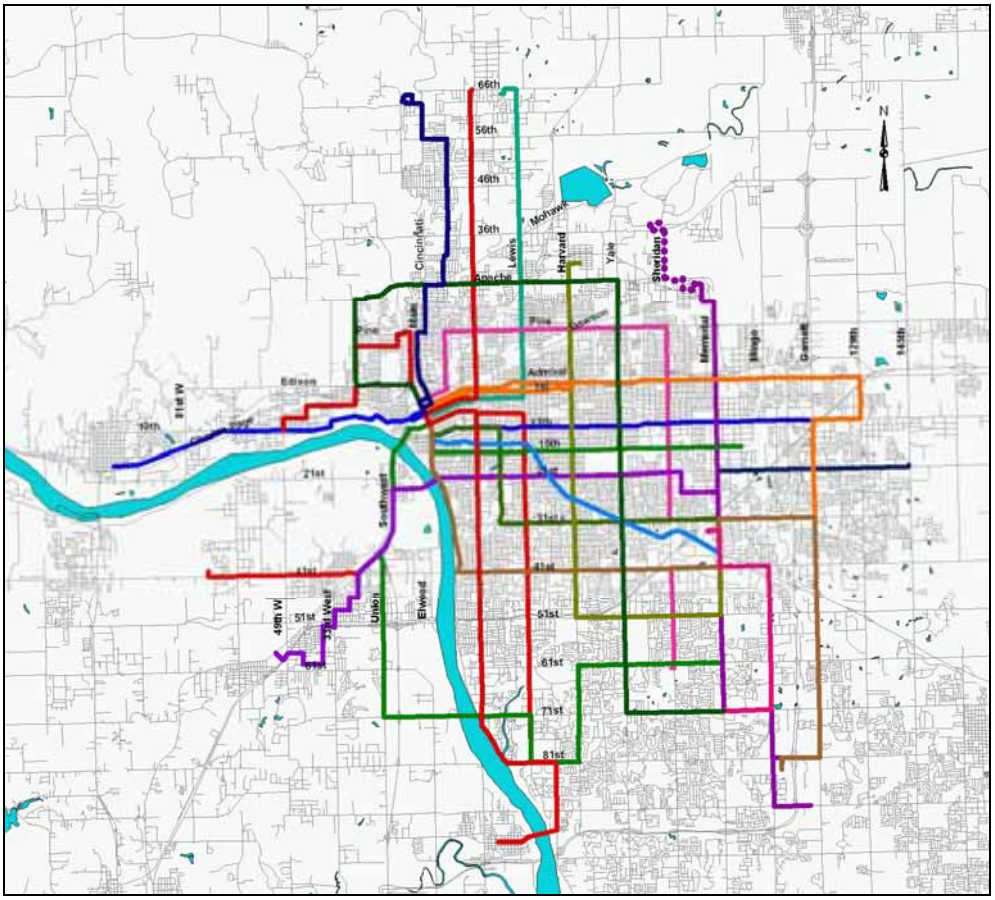
(a) All data are bus data only.

(b) Excludes expenses by non-transit agencies, contractors, and transit agencies not yet in operation.

Recently, a new system design was developed for Tulsa Transit by Perteet Engineering, Inc. to take a long-range look at transit needs and services in the Tulsa region and to plan for improved services. Cost parameters were set based upon costs in transit agencies serving areas similar to Tulsa. The project predicts an annual operating cost of $27,025,665 and a total of 138 peak hour buses with service being implemented incrementally until the year 2024.

The modified system design consists of grid-designed routes operating to and from the Tulsa Central Business District (CBD) and connecting important destinations and neighborhoods with the Denver Avenue and Memorial Midtown stations. The urban design is shown in *Figure 10* and the suburban design in *Figure 11*.

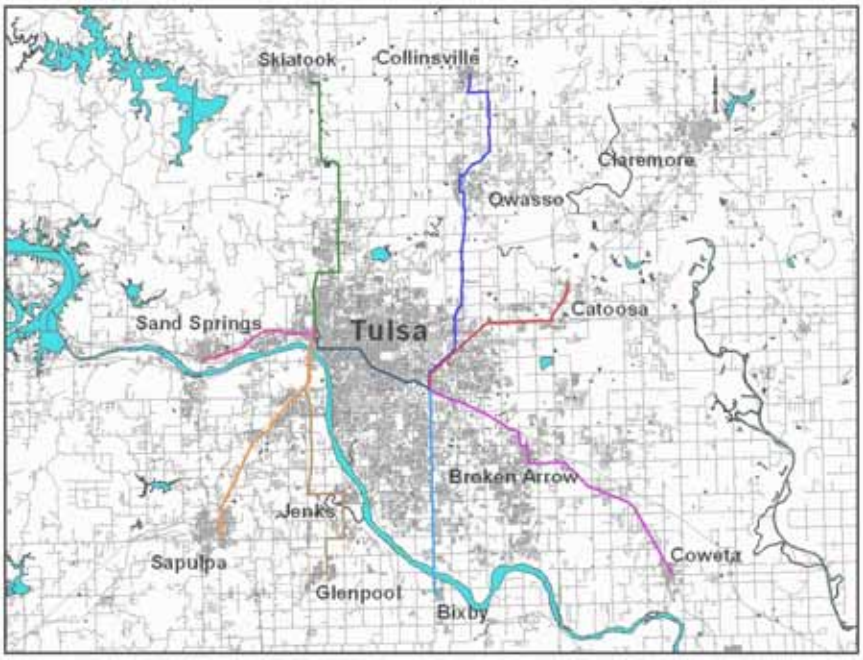
Figure 10: Recommended Tulsa Transit Urban System



It is envisioned that the suburban routes, designed to serve a number of communities surrounding the City of Tulsa, should be funded by the individual communities that they are designed to serve. The communities to be served by these suburban routes are:

- Catoosa (I-44/Highway 167)
- Owasso / Collinsville (I-44/Highway 169)
- Skiatook (Red Fork Expressway/Highway 11)
- Sapulpa (I-244/Alt. 75)
- Jenks / Glenpool (Highway 75)
- Bixby (South Memorial Drive/Highway 64)
- Broken Arrow / Coweta (Broken Arrow Expressway/Highway 51)

Figure 11: Recommended Tulsa Transit Suburban System



System enhancements should also be implemented to increase the probability people will choose transit over the automobile. According to a telephone survey conducted in December 2002 as part of the new system design project, Tulsa residents chose the following improvements as being very important to encourage an increase in ridership:

Table 5

Improvement	% Supporting Improvement
More bus shelters and benches	69%
Express service to major employers	67%
Service to outlying areas	63%
Better route and schedule information	56%
Make the bus system easier to understand	55%
Light rail transit where feasible	54%
More frequent bus service	53%

Sunday service	49%
Weekday bus service after 7 PM	48%
Saturday bus service after 6 PM	44%
A route closer to your home	41%
A route closer to your job or school	40%

The project doesn't detail the implementation of amenities to increase attractiveness of the bus service. However, possible improvements that would attract riders are:

- Well-lit passengers bus stops with shelters, benches, information kiosks, public telephones, and convenience for the mobility impaired.
- Automatic Vehicle Location System (AVL).
- Real-time passenger information.
- Low-floor buses.
- Advanced fare systems.
- Optimal headways: 15 minutes during peak hours and 30 minutes off-peak hours.
- Amenities for bicyclists.

It is proven by experience within several transit agencies that people react positively to both in-vehicle and bus-stop improvements. These improvements greatly affect their mode choices and their transit perceptions. The agencies that have invested in amenities believe that the benefits outweigh the costs.

5.2 Bus Rapid Transit (BRT)

Buses are considered the main choice of mass transit in the nation. More people ride the bus than any other mass transit alternative. Bus Rapid Transit was designed to innovate and improve bus services, providing higher speeds, better equipment, limited stops, new technologies, advanced fare collection systems, faster boarding, and improved shelters and stations. The Federal Transit Administration (FTA) defines BRT as the quality of rail transit combined with the flexibility of bus service. For BRT to be effective, it must be integrated with other transit systems such as traditional fixed route bus service, circulators, light rail transit, and demand responsive service, among others.

BRT can be developed quickly, economically, and incrementally and can be operated on a separate right-of-way so buses can achieve the speed and reliability critical to success. Some examples of running ways are: HOV lanes (seen in Dallas, Denver, Houston, Los Angeles, and Seattle), improved roadways, arterials (seen in Los Angeles), freeway medians or shoulders, railroad rights-of-way, aerial structures, or underground. Some cities that operate them on busways are Pittsburgh, Miami, and Charlotte.

Bus Rapid Transit ridership and average speeds are similar to those of Light Rail services with its main advantage being the flexibility of rerouting as needed, the possibility to operate on city streets, and the performance of light rail with lower capital and operating costs. When volume gets high enough, BRT can be converted to rail.

The Federal Transit Administration supports Bus Rapid Transit through funding sources such as the New Starts Program, the Bus Capital Program, CMAQ (Congestion Mitigation and Air Quality) Program, STP (through FHWA) and Urbanized Area Formula Grant Program. However, the New Starts Program is limited. It only funds Bus Rapid Transit projects that operate on separate right-of-ways or HOV Lanes. One option is to use the Federal Highway Administration's Value Pricing Pilot Program, which allows the expansion of High Occupancy Toll (HOT) Lanes in conjunction with the operation of a Bus Rapid Transit system. As seen in San Diego, toll revenues can be used

not only to fund the toll lanes but the bus system as well.

Some features of BRT include:

- **Running Ways:** Dedicated bus lanes that can be separated from the other traffic by barriers, road markings or signage. On highways, median strips are often used to avoid decreasing an auto lane. BRT can also run in bus-tunnels and bus-only roads.

Source: Charlotte Area Transit System.

Table 6

Comparative Analysis of BRT Running Ways

Running Way Options	Advantages	Disadvantages
Arterial ROW – Median Busways	▪ Allow higher speeds ▪ Less interference with other traffic ▪ Positive and permanent image ▪ No impact on right turns ▪ No impact on parking ▪ Easier enforcement	▪ Left turns for vehicles across the busway can be an issue ▪ Pedestrian access to the center of the arterial may be a problem ▪ Substantial right of way requirements, varying from 26 feet to 50 feet ▪ Center stations may be less safe

Arterial Offset / Interior Bus Lanes	▪ More reliable than curb lanes ▪ No impact on parking ▪ No impact on left turns ▪ Less impact on access ▪ Parking acts as buffer	▪ Stations areas take parking ▪ Interference from double parked vehicles ▪ Takes lane of traffic ▪ Potential safety problems with parkers
Arterial Curb Bus Lanes	▪ Least amount of street space ▪ No impact on left turns ▪ Can be implemented part time	▪ Impacts on right turns ▪ Impacts on parking ▪ Impacts on access ▪ Identity ▪ Tough enforcement
Arterial Contra flow Bus Lanes	▪ Least amount of street space ▪ Self enforcing ▪ Faster travel times	▪ Safety issues ▪ Impacts on parking ▪ Impacts on access ▪ Business and citizens resistance
Freeway Shoulder Busway	▪ Better pedestrian access ▪ Positive effect on land development ▪ Good Identity ▪ Normally grade separated	▪ Interchanges issues ▪ Right of Way
Freeway Median Busway	▪ Available ROW ▪ Good Identity ▪ Grade-separated	▪ Pedestrian and vehicle access ▪ Access costs ▪ Safety issues with contra flow ▪ High operation costs of contra flow
Busway on Railroad ROW	▪ Railroads ROWs available, both operating and abandoned ▪ High performance potential ▪ ROWs normally straight and level ▪ Limited number of crossings	▪ ROW width requirements ▪ Need to sustain safe physical separation between freight RR and BRT ▪ Poor pedestrian access ▪ Difficult negotiations with the railroad ▪ Normally far from development
Shared Running Way	▪ Increase passenger volumes	▪ Safety issues ▪ Only works in special cases
Tunnels and Shared Tunnels	▪ Complete grade separation ▪ Invisible on surface	▪ High costs ▪ Construction Impacts ▪ Ventilation systems

Elevated Busway	▪ Complete grade separation ▪ High Level of Service ▪ Identity	▪ High costs ▪ Visual and noise impacts ▪ Construction impacts
HOV Lanes	▪ Complete or partial grade separation ▪ Large available system ▪ More popular than busways	▪ Identity ▪ Low level of service ▪ Vehicle and pedestrian access issues ▪ Reversibility

- **Stations:** Attractive stations and bus stops. They should be permanent weather-protected facilities that offer convenience, accessibility, safety, amenities and information. These amenities, when combined with high-quality design, affect the public perception of transit in a very positive way. It is necessary to take into consideration spacing, design themes, and separation of uses when planning BRT stations, especially terminals that promote transfers between BRT and other connecting transit modes. To enable the bus to operate at high speeds, stations should be spaced as far apart as possible ranging from 2,000 to 7,000 feet on highways and from 1,000 feet along arterials[9]. Platform heights should match the

[9] TCRP Report 90 – Bus Rapid Transit Volume 1: Case Studies in Bus Rapid Transit – Transportation Research Board, 2003.

vehicles used. *Table 7* makes a comparative analysis of where the stations could be located.

Table 7

Comparative Analysis of Bus Stop Locations[10]

Stop Type	Advantages	Disadvantages
Near Side	▪ Minimizes interference when traffic is heavy on the far side of the intersection ▪ Passengers access buses closest to crosswalk ▪ Intersection available to assist in pulling away from curb ▪ No double stopping ▪ Buses can service passengers while stopped at a red light ▪ Provides driver with opportunity to look for oncoming traffic including other buses with potential passengers	▪ Conflicts with right turning vehicles are increased ▪ Stopped buses may obscure curbside traffic control devices and crossing pedestrians ▪ Sight distance is obscured for crossing vehicles stopped to the right of the bus. ▪ The through lane may be blocked during peak periods by queuing buses ▪ Increases sight distance problems for crossing pedestrians
Far Side	▪ Minimizes conflicts between right turning vehicles and buses ▪ Provides additional right turn capacity by making curb lane available for traffic ▪ Minimizes sight distance problems on approaches to intersection ▪ Encourages pedestrians to cross behind the bus ▪ Requires shorter deceleration distances for buses ▪ Gaps in traffic flow are created for buses re-entering the flow of traffic at signalized intersections	▪ Intersections may be blocked during peak periods by queuing buses ▪ Sight distance may be obscured for crossing vehicles ▪ Increases sight distance problems for crossing pedestrians ▪ Stopping far side after stopping for a red light interferes with bus operations and all traffic in general ▪ May increase number of rear-end accidents since drivers do not expect buses to stop again after stopping at a red light

[10] Federal Transit Administration web site – http://www.fta.dot.gov/brt/guide/stops.html

Mid block	▪ Minimizes sight distance problems for vehicles and pedestrians ▪ Passenger waiting areas experience less pedestrian congestion	▪ Requires additional distance for no-parking restrictions ▪ Encourages patrons to cross street at mid block (jaywalking) ▪ Increases walking distance for patrons crossing at intersections
Source: Table A-4, Appendix A, TCRP, original source: K. Fitzpatrick et al., *Guidelines for Planning, Designing, and Operating Bus-Related Street Improvements*. FHWA/TX-90/1225-2F, Texas Transportation Institute, College Station, TX. August 1990.		

- **Vehicles:** Environmentally friendly, easy-to-board vehicles with platforms on the same level as the bus floor. These vehicles should have multiple and wider doors, sometimes on both sides, to facilitate boarding on both center-island and side-station platforms.

Passengers board and alight via a special tube on Curitiba's central Transit Routes so that boarding is not delayed by fare collection.

Double-articulated bus on one of Curitiba's exclusive bus lanes

Bus guidance can be mechanical, optical, or magnetic and be of different sizes (50-140 places): Standard (40feet), articulated (60 feet) and Bi-articulated (80 + feet).

- **Intelligent Transportation Systems:** Use of Intelligent Transportation Systems (ITS) technology such as signal priority, real-time passenger information, service command/control, data collection, vehicle guidance and control, and automatic vehicle location system. ITS can also be used to expedite fare collection speeding up boarding and improving the system. Fare collection can be off-board or on-board multi-point. The use of ITS improves BRT efficiency and effectiveness and avoids additional personnel and infrastructure expenses.

- **Service Patterns:** Frequent, all-day service and simple route structure. Headways should be between 8 to 10 minutes during peak periods and 12 to 15 minutes during off-peak periods. With headways below 10 minutes, schedules are not required.

5.2.1 BRT Benefits:

BRT systems have shown to be very effective in several different cities around the world. Effectiveness can be measured by ridership, ridership growth, speed, travel time savings, and land-development benefits around transit stations. Ridership gains in cities that have implemented BRT systems are shown in *Table 8*.

Table 8

	Ridership Gain	**From Cars**
LA	+35% (3 years)	30%
Miami	+70% (4 Years)	
Boston	+100% (15 months after opening)	
Oakland	+25%	

Source: APA Transportation Planning Volume XXIX – Number 1 – March 2004

Table 9 displays typical operating speeds. Reported speeds from around the country have shown that BRT speeds are similar to the speeds achieved by Light Rail Transit (LRT).

Table 9

Typical Operating Speeds

Busway – Freeway Non-Stop	40 - 50 MPH
Busway – Freeway All-Stop	25 - 30 MPH
Arterial Streets	11 - 19 MPH

Table 10 records travel time savings compared to traditional bus service:

Table 10

Travel Time Savings

System	Travel Time Savings
Busway and Freeway Bus Lanes	32 - 47%
Bus Tunnel (Seattle)	33%
Arterial Street Busways / Bus Lanes	29 - 32%

Table 11 summarizes travel time savings in some systems already in service around the USA.

Table 11

Reported Travel Time Savings

		Travel Time (Min)		
City	**Facility**	**Before**	**After BRT**	**% Reduction**
Cleveland	Median Arterial Busway	41	32.75	20
Eugene	Arterial median Busway	27	15	46
Hartford	Busway	34.6	20.1	42
Honolulu	City Express	35	20	43

Los Angeles	HOV Busway	48	17	38
Seattle	Bus Tunnel	15	10	33

Source: TCRP Report 90 – Bus Rapid Transit – Volume 1: Case Studies in Bus Rapid Transit

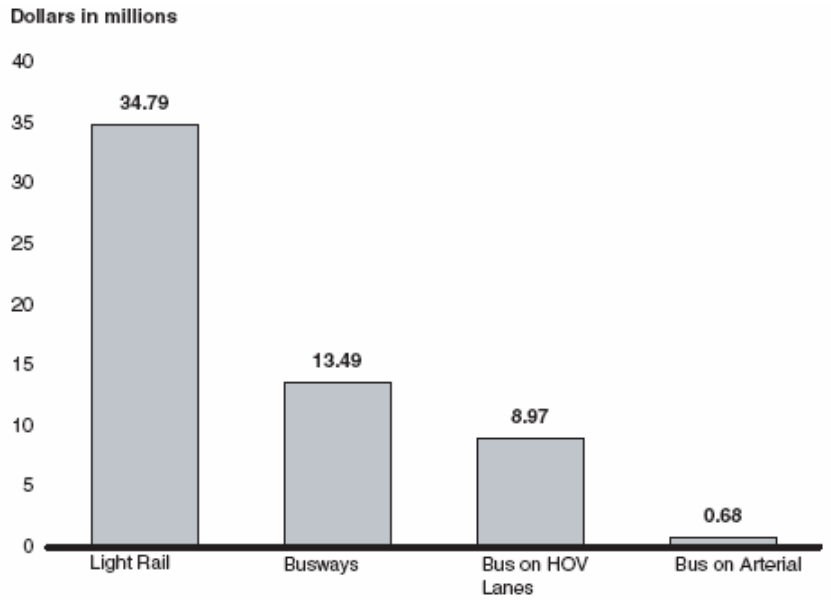
Cities that have implemented BRT systems have seen savings in operating and maintenance costs, reduction in accidents, fuel consumption and environmental impacts (like noise and air pollution), as well as economic and land development benefits around stations.

5.2.2 BRT Costs:

Implementation costs vary according to location and complexity but are generally lower than LRT costs – see *Figure 10*.

Figure 10

Capital Cost per Mile for Light Rail and Bus Rapid Transit



Notes: Cost escalated to fiscal year 2000 dollars.

Average Light Rail capital costs are for 13 cities that built 18 Light Rail lines since 1980. Busway capital costs are for nine busways built in four cities; in two cities these facilities were subsequently

[10]Project capital costs typically include the costs to plan, design, and construct a project.

Source: GAO-01-984 Bus Rapid Transit Shows Promise

Estimated costs per mile are $272 million for bus tunnels, $7.5 million for dedicated surface busways, $6.6 million for arterial median busways, $4.7 million per mile for guided bus operations and $1 million for mixed traffic or curb bus lanes. [11] *Table 12* summarizes the development costs of some systems in service in the USA.

Table 12

Development Costs of Selected BRT Systems

City	Miles	Cost ($Million)	Cost/Mile ($Million)
Bus Tunnels			
Boston (Silver Line)	4.1	1,350	329
Seattle	2.1	450	214
Busways			
Hartford	9.6	100	10
Miami	8.2	59	7
Los Angeles	12	75	6

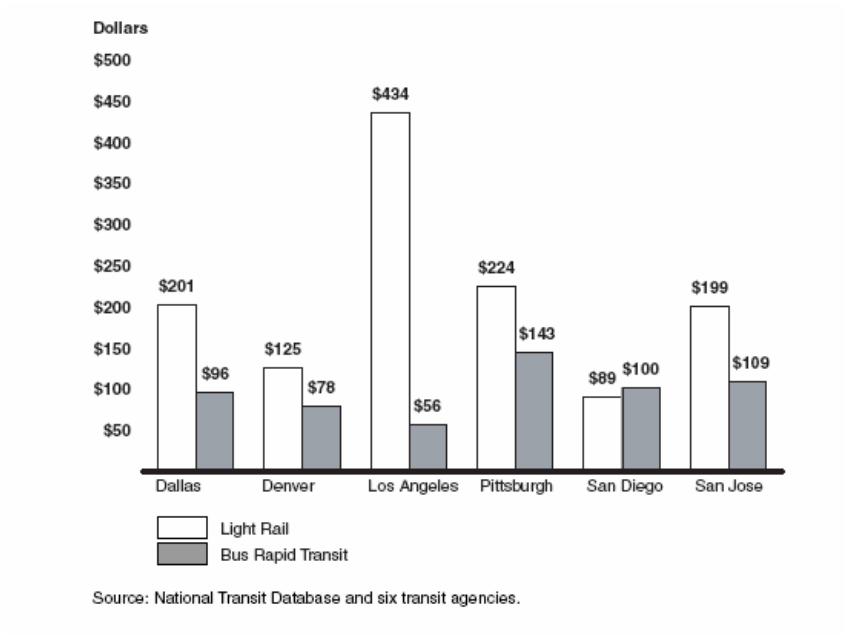
Source: TCRP Report 90 – Bus Rapid Transit – Volume 1: Case Studies in Bus Rapid Transit

Operating costs are also lower than LRT costs. In Pittsburgh, operation and maintenance cost per passenger-mile averaged $.65, while light rail averaged $.84 per passenger-mile.

[11] APA Transportation Planning Volume XXIX – Number 1 – March 2004

Figure 11

Operating Costs per Vehicle Revenue Hour, 1999



Source: GAO-01-984 Bus Rapid Transit Shows Promise

BRT should be implemented in cities where the urban population exceeds 750,000 and CBD employment is between 50,000 to 70,000. BRT can be more effective than light rail transit in dense, compact business districts. In residential areas, a minimum density of five to eight dwelling units per acre is required. Dedicated right-of-way has to be justified by the possibility of carrying more passengers than an equivalent traffic lane.

There are a growing number of cities evaluating and considering implementing BRT. This alternative has shown very effective and cost efficient in many cities in the USA and around the world. It is very important that the differences between conventional bus system and BRT and the possibility of incremental service development are made clear to community leaders and citizens. An integration of transportation and land use planning is essential to the success of BRT systems.

5.3 Light Rail Transit (LRT)

Light Rail, also known as streetcars, trolleys, or tramways, is a system that has the ability to operate single cars or short trains and is operated by an overhead source of electrical power. It can run on streets with other traffic, on elevated structures, or in subways. LRT systems have the following basic elements: infrastructure, rolling stock, and fixed equipment.

Infrastructure is composed of the trackways, stations and storage yards that allow vehicle maintenance and overnight storage. Stations are usually spaced 1.5 miles to 1 mile apart. The tracks are the costliest elements of the LRT system. Trackways can be placed on the surface of the ground, below or above the surface.

- An exclusive guideway provides a fast and safe operation of the system. It uses a street right-of-way or existing rail tracks and is protected from the street traffic by curbs. The minimum width required is 26 feet for two tracks, and therefore a street 100 feet wide, curbface to curbface. A six-lane street or equivalent would also accommodate an exclusive guideway. LRT can also be implemented along a wide median strip in a large street where safety barriers can be accommodated.
- A shared guideway permits the LRT cars to travel sharing the street with other traffic. The train cars are usually shorter in length to avoid blocking intersections and the speeds are usually lower than those of exclusive guideways. Shared guideway can be implemented on streets with approximately 65 feet from curbface to curbface. However, there are examples around the country where LRT was implemented on streets with 40 feet curbface to curbface.

The rolling Stock is comprised of one or more fleet of railcars. LRT cars are versatile and can be designed to operate in very specific environments. They come in a

variety of shapes and sizes; most are articulated, but some places operate traditional one-piece cars. LRT cars can travel as fast as 65 miles per hour. They are passenger-friendly, providing smooth rides, comfortable seats and aisles, and pleasant temperatures inside without any loss of performance. Passengers also enjoy freedom from vibration, odor and noise. Many of the new systems have low-floor cars, providing level boarding friendly to passengers with disabilities.

Fixed Equipment consists of an operation and maintenance center, the electric power supply, signals, and communication facilities.

5.3.1. Advantages of using LRT: [12]

- Flexibility in design and implementation compared to any other rail-based service. The line can be built incrementally, vehicles can be sized to fit demand, and the system can be upgraded to rapid transit.
- Mechanical efficiency and power conservation.
- Reliability and safety of operations.
- Labor productivity considering that LRT requires only one person to operate it no matter the size. Easy maintenance.
- There is greater acceptance of LRT by policymakers and citizens than any other transit mode, except for commuter rail, for their quality and attractiveness of ride.
- There are fewer environmental impacts.
- LRT enhances the status symbol of any city. It integrates into the community and with other modes of transportation. People don't hide their disappointment when discussions shift from rail to bus.
- Currently LRT costs are reasonable and capacity has been responsive to demand.

[12] Grava, Sigurd - Urban Transportation System: Choices for Communities – McGraw-Hill, 2002

5.3.2. Disadvantages of using LRT:[13]

- LRT system construction requires a large capital investment.
- Fixed alignment.
- Interference with traffic and overhead wires.

According to a study prepared by Wendell Cox Consultancy in February 2000, the transit market share has risen from 1.02% to 1.10% and light rail has captured only 0.61% of new travel. The study also mentions that US Census Bureau data indicates a drop in transit market share in all metropolitan areas that opened LRT systems in the 1980s.[14]

5.3.3. Costs:

Because of LRT design and implementation flexibility, capital costs vary significantly. In 13 U.S. cities that have built LRT systems, costs ranged from $12.4 million per mile to $118.8 million per mile (year 2000 dollars) with an average of $34.8 million per mile[15]. Costs can be mitigated when existing tracks that meet the needs can be used, but increase significantly if tunnels or elevated structures need to be built or right-of-ways need to be acquired. Light Rail vehicle costs an average of $2.3 million each. Operating costs vary from city to city and can be calculated by cost per revenue mile. Operating costs in the 13 cities mentioned above varied from $4.20 to $15.60 per revenue mile, with an average of $11.74 per revenue mile[16]. Operations and Maintenance expenses are comparable to buses. See *Table 13* for some Light Rail Systems opened in North America.

[13] Ibid.
[14] New Light Rail in the United States: Promise and Reality – Wendell Cox Consultancy, February 2000.
[15] Las Vegas Valley Transit System Development Plan - Parsons, May 2002.
[16] Ibid.

Table 13

City	Operating Agency	Length of Track	Weekday Ridership	Total Capital Cost, $ millions	Average Cost per Km, $ millions
Dallas	Dallas Area Rapid Transit Authority	46.7 mi	35,000 (1998)	$860 (1995)	$27
Denver	Regional Transportation District	10.3 mi	16,000 (1994)	$116.5 (1994)	$14
Los Angeles	LA County Metropolitan Transportation Authority	14 mi	38,000 (1995)	$895 (1990)	$40
Salt Lake City	Utah Transit Authority	29.6 mi	19,000 (1999)	$312 (2000)	$13
San Jose	Santa Clara Valley Transportation Authority	56.3 mi	20,000 (1995)	$540 (1987)	$14
St. Louis	Bi-State Development Agency	17 mi	46,000 (1998)	$464	$17

Source: Urban Transportation Monitor; May 12, 1995

Available data for LRT suggests that it is appropriate for communities with a population size of 250,000 or over and a minimum density of nine people per acre. LRT can be developed as the principal transit network such as in Portland, Oregon, San Diego, and Dallas or as a corridor with strong trip attractions at both sides and residential areas within walking distance. Ridership can be placed in the range of 7,000 to 57,000 passengers per day with an average of 29,000 daily riders depending on a wide variety of factors such as frequency of service, number of stops, hours of operation, and customer demand.

In September 2001, Portland opened a network of streetcars in the central city area. It was initially projected to serve 4,000 riders but has exceeded 8,000 riders per day. New development along the streetcar line already exceeded $100 million. According to the National Transit Database, Sacramento carried less than 14 million passengers in its all-bus operation. In 1998, the system carried more than 28 million riders with the LRT

system attracting more than 8 million riders and the bus system growing to nearly 20 million riders[17].

LRT has been the preferred transportation mode within the past decade. It not only provides a comfortable and reliable means of transportation, but it can also have a positive impact on land development.

[17] Transportation Research Board, This is Light Rail Transit, November 2000.

5.4 Commuter Rail System

Commuter rail is a type of passenger rail service that offers attractive, high-quality, long-distance transit service made within metropolitan regions. It carries commuters on routes that range between 20 to 50 miles from the city center with few station stops. Since commuter rail transit operates primarily on existing freight tracks usually sharing the lines with freight trains, it needs to be fully compliant with Federal Railroad Administration (FRA) safety guidelines. Sharing tracks with freight service eliminates costs associated with right-of-way and infrastructure. However, it imposes limitations on schedules and requires improvements to increase capacity and speeds.

The most common type of equipment used for commuter rail service is diesel or electric locomotive-hauled trains. Self-propelled diesel and electric cars are also used. The stations have to be concerned with the flow and safety of passengers with central or side, low or high platforms, and weather-protected waiting spaces. The distance between stations is usually three to five miles. It is essential that the stations have loading bays for feeder services such as buses or taxis, kiss-and-ride spaces and park-and-ride facilities.

Most commuter systems still use the traditional fare collection, with passes purchased before boarding. Control systems are also crucial for the safety of the rail network. The main concerns are train collisions, derailments, fires, and pedestrian and cars entering the tracks. Since commuter rail uses existing infrastructure, facilities for storage and maintenance of rolling stock are accommodated with these already existing operating systems. In cases where such facilities need to be built, it is necessary to deal with zoning issues and have considerable acreage of land available, preferably at the end of a line or where several lines cross.

New rail line services are usually initiated on weekday peak periods, inbound trains in the morning and outbound trains in the evenings with frequencies of 20, 30 or 60 minutes. Population density around the stations is not as relevant to commuter rail ridership as it is for light rail. The Central Business District (CBD) size and density have

more influence on commuter rail operations. The service offered by commuter rail is less frequent, faster, and it requires extensive parking availability. Additionally, service can be provided to areas with lower residential densities and higher incomes further from the CBD.

Table 14

Some Physical Characteristics of Commuter Rail

Number of seats in regular coach	Up to 128
Number of seats in bi-level coach	Up to 175
Capacity with standees	360
Number of cars in a train	1 to 12
Maximum running speed	80 mph
Usual average operating speed	18 to 50 mph

Source: Grava, Sigurd - Urban Transportation System: Choices for Communities – McGraw-Hill, 2002

5.4.1. Costs

Across the U.S., capital costs range from $2 million to $17 million per mile depending on the unique situation of each proposed system. Included in the capital costs are rail track and site improvements, stations, parking, signals, right-of-way, maintenance and stocking facilities, and rolling stocks that varies from $1.3 million to $6 million each. Operating costs are also unique for each situation and depend on crew requirements and vehicle miles.

The high costs associated with the implementation of a commuter rail system cannot be justified when providing service to just a few thousand commuters. It can only become a transportation mode option if the system is already in place and the rolling stock can be acquired for a low price, mitigating the high costs, and demand is sufficient to justify it.

5.4.2 Ridership

Ridership depends on several different factors such as number of lines operating, hours and frequency of service.

5.4.3 Advantages of Commuter Rail

- Efficient, fast and comfortable services.
- Reliability and safety.
- Fairly quick implementation of the system if existing resources are used.
- Good public image attractive to the citizens and decision makers.

5.4.4 Disadvantages of Commuter Rail

- Existing right-of-way has to be used and, therefore, there is no flexibility in the location of the routes.
- Conflicts to accommodate passenger service and freight services on same tracks.
- High costs of implementation if improvements on the existing facilities are necessary and new rolling stocks are need.
- Environmental considerations such as noise, vibration and visual impacts.
- Safety issues.

Almost all major cities in the United States have examined proposals for commuter rail service. Downtown Dallas was connected to Fort Worth; in Vermont, service is provided linking Burlington to Charlotte; new stations and high-level platforms are being built in Connecticut; and Chicago is examining new major extensions.[18]

[18] Mass Transit – "Commuter Rail Update 2001", March 2001 issue.

In the Minneapolis-St Paul region, a proposal for a commuter rail line is under way. A commuter rail system is more attractive to commuters and decision makers than a bus system. It is believed that the system is cheaper than a BRT system, because existing rails are utilized while new BRT lanes would have to be built.

A commuter rail line between Broken Arrow and downtown Tulsa has been contemplated for over 10 years. Engineering studies to determine the feasibility of the plan have not been conducted but the Regional Mobility Plan, a study developed by consultants in June 1993 for the Metropolitan Tulsa Transit Authority, recommends implementation of the system. According to the plan, enough riders would likely be attracted to the system to support the capital and operating investment required to build it.

Figure 12 shows the proposed location of the commuter rail line. The system would have a total of 14 miles running from the vicinity of Main Street in Broken Arrow to the vicinity of Union Station in downtown Tulsa. Park-n-ride lots would be located at the Broken Arrow Station and also at an intermediate stop located near Skelly Drive. The bus system and the paratransit system would support the commuter system connecting the lines with the three rail stations, providing convenient feeder transit service.

Figure 12

The proposed commuter rail system would operate during peak periods with three trips inbound in the morning and three trips outbound in the evening. Service levels would depend on achieved ridership. In 1993, when the report was prepared, preliminary suggested capital costs, based on experience in other cities, ranged from $25 million to $35 million. These costs included upgrading the track and signals to Federal Railroad Administration standards, building three stations, and buying or leasing five vehicles. Operating costs would be in the range of $2 million to $3 million annually. To operate passenger service on these lines, operating agreements would be required since the tracks are currently being used for freight operations by Union Pacific and Burlington Northern Railroads.

5.5 Bicycle / Pedestrian

The 2025 Long Range Transportation Plan (LRTP) for the Tulsa Transportation Management Area (TMA) established specific goals and policy strategies for the development of bicycle and pedestrian facilities within the TMA. Major gains in this area have been accomplished with the development and continuing implementation of the Tulsa TMA Trails Master Plan. Additionally, gains in strategy implementation have been improved further by cooperative efforts between the Tulsa Metropolitan Area Planning Commission (TMAPC) staff and MPO staff.

Tulsa TMA Trails Master Plan was adopted in July 1999 and proposed the construction of 283 miles of off-road multipurpose trail and 207 miles of on-street linkages. Tulsa Metropolitan Area has 34 miles of existing trails and 19 miles of funded trails in the planning and early construction phases for a total of 53 miles. The City of Tulsa, City of Sand Springs, City of Broken Arrow, City of Jenks, and the City of Claremore have completed trails identified by the Trails Master Plan or have funded projects under development as identified by the Trails Master Plan.

Example of a multiuse trail within the TMA

The City of Tulsa also received funds from the CMAQ program for the construction of 18 miles of on-street bicycle route improvements identified in the Trails Master Plan. INCOG works with advocate user groups through the Safe Routes to School Program and the TMA Bicycle Advisory Group to encourage the use of the metro trails system as a means of alternate transportation and a safe way to exercise.

Total cost to implement all of the trail corridors as identified in the Trails Master Plan is estimated at $75,063,895. The majority of the trail and bikeway improvements in the TMA have been funded through the Transportation Enhancements Program, which was established with the passage of the Transportation Equity Act (TEA 21). It is anticipated that this program will be reauthorized by Congress which will continue to provide an available source of funds for trail and bikeway construction.

Example of site utilizing a radial sidewalk connection from the interior of the development to the arterial sidewalk, pedestrian multiuse trail, or transit shelter/stop

Recently, the MPO staff and the TMAPC staff began working together to further the goals established in the Tulsa TMA Trails Master Plan and the goals for pedestrian movement contained in the LRTP. The first major accomplishment was the inclusion of MPO staff into the Technical Advisory Committee (TAC) of the TMAPC. The MPO staff now reviews land development proposals for conformance with the LRTP and the Trails Master Plan. Once the MPO staff has completed their review of the items under consideration by the TAC, comments are compiled and then transmitted to the TMAPC staff for distribution to the TAC members and applicants. Typical MPO requests are for trail easements, sidewalk connections, and pedestrian circulation plans. Thus far success has been marginal, but the development community is becoming more conscious of pedestrian planning, and the first application for a Planned Unit Development (PUD) with planned pedestrian facilities was recently submitted. The PUD development process represents the best opportunity to influence site design to meet the needs of the pedestrian.

The MPO staff is also investigating other permitting and development processes that affect the provision of pedestrian facilities such as sidewalks. The City of Tulsa subdivision regulations require sidewalks only on collector streets. However, applicants for commercial subdivision plats are required to provide sidewalks across all arterial frontages, as outlined in the Privately Financed Public Improvement (PFPI) review process. MPO staff is hopeful that through cooperation and demonstration of need, provision of sidewalks will become standard procedure.

Pedestrian circulation and facility provision has been consistently raised by MPO staff. In June of 2003, at the MPO's request, the Federal Highway Administration (FHWA) conducted a walkable communities workshop for area government and planning officials. The response was positive with representatives from the City of Tulsa (COT) Public Works, COT Urban Development, COT Planning Commission, and communities from around the region participating. The workshop centered around engineering alternatives that enhance the walking environment and provide for safe pedestrian movement. The FHWA representative encouraged the participants to consider pedestrian

needs in their engineering designs and asked them to develop solutions for some local problematic areas through an on-site case study.

The ultimate aim of these strategies is to improve multi-modal connectivity, providing viable transportation choices. Aggressively seeking out new funding opportunities and working with local entities on implementing solutions in pedestrian safety should be major focuses of future planning efforts. The best hope of achieving these long-term goals, as outlined in the LRTP and trails master plan, lies in continued cooperation, implementation, and education regarding the need for pedestrian mobility.

5.6 HOV / HOT Lanes

High occupancy vehicle (HOV) lanes and high occupancy toll (HOT) lanes work well as a part of a transportation system to move more people per vehicle mile traveled. HOV lanes are lanes reserved for use by high occupancy vehicles of 2+, 3+, or 4+ persons depending on the facility. When HOV lanes are constructed with the primary purpose of moving more people they often succeed with proper planning and design from the conceptual stage.

The HOV concept is to encourage greater use of modes, such as transit, carpool, and vanpool therefore moving more people not necessarily more vehicles as shown in Figure 13. HOV lanes have the potential to improve the person-moving capability and reliability, and efficiently utilize the available roadway infrastructure and transit fleet.[19]

Figure 13. Number of Vehicles Needed to Carry 45 People

Bus	h	1
Vanpool (8 people per van)		6
Carpool (3 persons per carpool)	j j j j j j j j j j j j j j j	15
Carpool (2 persons per carpool)	o o o o o o o o o o o o o o o o o o o o o o	22
Single Occupant Vehicle (1 person per vehicle)	n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n n	45

The common objectives for utilizing an HOV lane are:

- Increase the average number of persons per vehicle

[19] Chuck Fuhs and Jon Obenberger, "HOV Facility Development: A Review of National Trends" Paper No. 02-3922

- Preserve the people-moving capacity of the freeway
- Improve bus operations, and
- Enhance mobility options for travelers.

There are several types of HOV facilities:

- **Exclusive HOV Facility, Separate Right-of-Way**: A roadway or lane is developed in a separate right-of-way and designated for exclusive use by high occupancy vehicles. Most are designed for and utilized by buses only.[20]
- **Exclusive HOV Facility, Freeway Right-of-Way**: A lane constructed within the freeway right-of-way that is physically separated from the general-purpose freeway lanes and used exclusively by HOVs for all or a portion of the day. Most are separated by a concrete barrier. These are usually opened to buses as well as vanpools and carpools.[21]

- **Concurrent Flow Lane**: These are defined as a freeway lane in the same direction of travel, not physically separated from the general-purpose lanes designated for HOV use for all or a portion of the day. These are usually but not always located on the inside shoulder and separated with paint striping. These are generally open to buses, vanpools and carpools.[22]

[20] Katherine F. Turnbull, "An Assessment of high Occupancy Vehicle (HOV) Facilities in North America, August 1992
[21] Ibid
[22] Ibid

- **Contraflow Lane**: This facility is a freeway lane in the off peak direction of travel, typically the innermost lane designated for exclusive use by HOVs traveling in the peak direction The lane is separated from off-peak direction traffic by some type of changeable treatment. These lanes are usually operated during peak periods only.[23]

- **Busways:** These are HOV lanes dedicated to bus-only "Bus Rapid Transit (BRT)-type" of operation and is located in separate rights-of-way.
- **Queue Bypasses for HOVs:** These are isolated treatments to allow eligible traffic to circumvent traffic bottlenecks, such as ramp meters, ferry queues, or toll plazas.

Some operating characteristics associated with HOV lanes include:

- Number of lanes in operation
- Length of lanes in operation
- Vehicles allowed to use the facility
- Vehicle occupancy requirements
- Hours of operation
- Type of separation from the general-purpose lanes
- Need for daily set-up

Screening criteria to consider the applicability of an HOV lane include as least 20 minute delays per vehicle in the general-purpose lane to warrant the need for an HOV

[23] Ibid

lane, although in Texas as little as 10 minute delays have proven successful.[24] Figure 14 lists screening criteria recommended by NCHRP Report 414- The HOV Systems Manual.[25] "HOV lanes are a strategy that local governments have employed to reduce traffic congestion. The idea is simple. Single-occupant (SOV) travel is wasteful, particularly at peak travel times. Restricting certain highway lanes to exclusive use by multi-occupant vehicles encourages carpooling, vanpooling, and transit ridership. The result is a familiar sight – congested traffic in the general-purpose highway lanes while vehicles travel near the speed limit in the parallel HOV lanes."[26]

- *Congestion Levels* - recurring peak hour speeds of 30 mph or less
- *Travel Patterns* – work trips to densely developed activity centers
- *Current Bus and Carpool Volumes* – a corridor with high levels of current HOVs usually represents a better candidate. The manual include minimum "threshold" values for various kinds of HOV facilities (400-800 existing carpools/buses per hour for HOV lanes similar to those in Texas.)
- *Travel Time Savings and Trip Reliability* – An HOV lane should save at least one minute per mile, with overall savings of at least five minutes and preferably more than eight minutes.
- *Trip Distance* – Corridors with long trips are more likely to attract substantial HOV traffic.
- *Support Facilities and Services* – Facilities such as park and ride lots, direct access ramps and enforcement areas, and services such as transit and rideshare contribute significantly to the success of HOV lanes.

5.6.1 Costs

Constructions costs and operations play an important role in determining the effectiveness of an HOV system. There are a large number of factors that have to be considered that can vary the cost from project to project. Some of those factors include the need for bridges or other structures in the corridor, environmental impacts, right-of-way needs, and utility relocation to name a few. Other costs associated include:

- Operation and maintenance costs
- Park costs
- Enforcement costs
- Operating Costs
- Bus/Transit fares

[24] Wm R Stockton, P.E., Ginger Daniels, P.E., Douglas A Skowronek, P.E., and David W. Fenno, P.E., "The ABC's of HOV The Texas Experience", September 1999.
[25] HOV Systems Manaula. National Cooperative Highway Research Program, Project 3-53. Transportation Research Boar, National Research Council, Washington, D.C. February 1998
[26] Katherine F. Turnbull, History of HOVs, Texas Transportation Institute, date?

These costs will vary too according to the size of the system and what is required to operate it.[27] Facility-type and site selection are the main considerations in determining actual implementation costs, and HOV treatments are least expensive when implemented in existing highway rights-of-way. When such lanes are unavailable, HOV lanes are still found to be cost-effective when compared to other alternate transportation modes or highway widening.

5.6.2 Travel Time/Congestion Relief

The principle idea behind the HOV lane is to move more people by increasing the number of carpools, vanpools, and transit riders. While HOV lanes offer many benefits to riders, it is important to promote HOV implementation as a component of an overall transportation strategy rather than a "cure" for congestion issues. Motorists may feel frustrated and avoid using HOV lanes if they believe expectations, however unrealistic, were unmet. Users are most interested in time savings. Without significant time savings, the number of HOV users will decrease, and the facility will be less likely to attract single occupant drivers. HOV facilities typically offer a one minute per mile savings, and a minimum per-trip savings of five minutes. A preferred time savings of 8 to 10 minutes per trip is desired. In Virginia, a 28-mile reversible HOV lane carries an average of 10,400 person trips and 2,800 vehicles in the AM peak hour and provides an average travel time savings of 31 and 36 minutes for the AM and PM peak travel periods, respectively.[28]

The level of service desired for a good performance measure is C12 which occurs somewhere in the area of 1,200 vehicles per hour per lane for most facilities.[29] Each facility will vary and have a level of service that is determined to be satisfactory. Traffic volumes will have to be monitored to determine if acceptable volumes are being

[27] Richard S. Poplaski and Michael J. Demetsky, HOV Systems Analysis – Final Report, Virginia Transportation Research Council, VTRC 94-R13, January 1994
[28] Chuck Fuhs and Jon Obenberger, HOV Facility Development: A Review of National Trends, Paper No. 02-3922

maintained. Monitoring volumes is important because as the facility reaches capacity, adjustments will be needed to avoid any slowdowns on the system.[30] Adjustments can be made by increasing the number of person per vehicle, perhaps changing from a 2+ carpool to a 3+ carpool occupancy requirement in the HOV lane.

By attracting more users into the HOV lane, either by increasing the number of carpools, vanpools, or transit riders, the thought is to get those persons out of the general-purpose lanes, thereby alleviating congestion and reducing vehicle miles traveled. This in turn also has an impact upon the air quality or emissions reduction due to the decrease of vehicle miles traveled and traffic flowing faster, which reduces running and trip-end emissions. Running emissions are reduced because of the increased use of buses, vanpools, and carpools resulting in fewer vehicles on the road and higher speeds associated with uncongested operations in HOV lanes.[31] "If additional trips are not taken, then HOV lanes will also reduce trip-end emissions. Trip-end emissions result from the initial inefficient engine operation when the trip begins (cold start) and evaporation of fuel from a hot engine at the end of the trip (hot soak)."[32] HOV systems are a complement to alternative transportation modes and roadway improvements, offering congestion-management strategies rather than eliminating congestion.

Figure 15 gives an overview of the suggested objective that an HOV lane is to provide and the measures of effectiveness by which these objectives can be calculated as reported in the August 1992 Executive Report "An Assessment of High Occupancy Vehicle (HOV) Facilities in North America".[33]

Figure 15

Objective	Measure of Effectiveness

[29] Richard S Poplaski, Michael J Demetsky, HOV Systems Analysis – Final Report, January 1994
[30] Ibid
[31] Ibid
[32] Ibid
[33] Katherine F. Turnbull, An Assessment of High Occupancy Vehicle (HOV) Facilities in North America, August 1992

• The HOV facility should improve the capability of a congested freeway corridor to move more people by increasing the number of person per vehicle	• Actual and percent increase in the person-movement efficiency • Actual and percent increase in average vehicle occupancy rate • Actual and percent increase in carpools and vanpools • Actual and percent increase in bus riders
• The HOV facility should increase the operating efficiency of bus service in the freeway corridor	• Improvement in vehicle productivity(operating cost per vehicle-mile, operating cost per passenger, operating cost per passenger-mile) • Improved bus schedule adherence (on-time performance) • Improved bus safety (accident rates)
• The HOV facility should provide travel time savings and a more reliable trip time to HOVs utilizing the facility	• Peak-period, peak-direction travel time in the HOV lane(s) should be less than the adjacent general-purpose freeway lanes • Increase in travel time reliability for vehicles using the HOV lane(s)
• The HOV facility should have favorable impacts on air quality and energy consumption	• Reduction in emissions • Reduction in total fuel consumption • Reduction the growth of vehicle-miles of travel (VMT) and vehicle-hours of travel (VHT)
• The HOV facility should increase the per-lane efficiency of the total freeway corridor	• Improvement in the peak-hour per-lane efficiency of the total facility
• The HOV facility should not unduly impact the operation of the freeway general purpose lanes	• The level of service in the freeway general-purpose lanes should not decline
• The HOV facility should be safe and should not unduly impact the safety of the freeway general-purpose lanes	• Number and severity of accidents for HOV and general-purpose lanes • Accident rate per million vehicle-miles travel • Accident rate per million passenger-miles of travel
• The HOV facility should have public support	• Support for the facility among users, non-users, general public, and policy makers • Violation rates (percent of vehicle not meeting the occupancy requirement)
• The HOV facility should be a cost-effective transportation improvement	• Benefit-cost ratio

"Given current trends, it appears that mobility, traffic congestions, and air quality issues will continue to be a major concern for metropolitan areas throughout the county. HOV facilities represent one viable approach to addressing some of these concerns. When HOV lanes are implemented in appropriate corridors and operated properly, HOV projects are an effective means of moving people instead of vehicles. The travel time savings and travel time reliability provided by HOV facilities offer incentives that many

commuters find attractive enough to change from driving alone to taking the bus, carpooling, or vanpooling."[34]

5.6.3 HOT Lanes

HOV lanes have proven successful in many metropolitan areas but there is still the view point by non-users that they are being underutilized. Critics claim that HOV lane users create vacancies for additional cars in traditional lanes, increasing congestion, pollution, and sprawl. With the increasing pressure from the public, legislators and transportation agencies face the issue of how to achieve better harmony among the users of the transportation system. At the same time they are still faced with the issues of congestion and finding a viable means of funding for transportation projects. High occupancy toll (HOT) lanes can address both issues. HOT lanes open HOV lanes to single occupant drivers willing to pay for the privilege of traveling in an uncongested lane. Many Americans support using these tolls, which can total millions of dollars in toll revenue, to improve highways and other transportation modes. HOT lanes combine HOV and pricing strategies management, to maintain free flow conditions even during rush hours. The Federal Highway publication, "A Guide for HOT Lane Development" lists the appeal of the HOT lane concept as the following three points:

- It expands mobility options in congested urban areas by providing an opportunity for reliable travel times to users prepared to pay a significant premium for this service;
- It generates a new source of revenue which can be used to pay for transportation improvements, including enhanced transit service, and
- It improves the efficiency of HOV facilities which is especially important given the recent decline in HOV mode share in 36 or the 40 largest metropolitan areas, along with the decline in the number of carpools nationwide.[35]

[34] Ibid
[35] Ibid

HOT lanes also offer:

- An alternative to getting stuck in traffic, or a form of "travel insurance" in the form of guaranteed on-time arrival and just-in-time deliveries.
- Transit benefits: They can speed up bus travel and make bus service more reliable, and
- Reduced congestion in regular lanes as some drivers make the switch to the premium lanes.[36]

"HOT lanes are limited-access; normally barrier-separated highway lanes that provide free or reduced cost access to qualifying HOVs, and also provide access to other paying vehicles not meeting passenger occupancy requirements. By using price and occupancy restrictions to manage the number of vehicles traveling on them, HOT lanes maintain volumes consistent with uncongested levels of service even during peak travel periods. Most HOT lanes are created within existing general-purpose highway facilities and offer potential users the choice of using general-purpose lanes or paying for premium conditions on the HOT lanes."[37]

5.6.4 Toll Collection/Fees/Costs

To avoid congestion at toll collection facilities, electronic toll collection devices are utilized with the consumer generally purchasing a prepaid transponder/detector for their vehicle. Variable message signs notify motorists of the cost for using the HOT lane prior to the entrance. The HOT lane tolls may vary depending upon the usage, with higher tolls during peak-hours and other congested times. Users can avoid increased fees by commuting during off-peak hours, selecting another route, or using alternative

[36] Washington DC Region – A HOT Lane Incubator, Innovation Briefs, Volume 15 Number 1, January/February 2004

transportation modes. "As the number of vehicles in the HOT lane rises so do the toll rates."[38]

HOT lanes can be created through new construction or existing lane conversion, with conversion of HOV lanes to HOT operation being the most popular option. Generally toll revenues collected from the HOT lane will cover the cost to convert an HOV lane over to a HOT operation. Capital expenses include the purchase of dividers, markers, electronic signs, and enforcement equipment, as well as video equipment and software for electronically accessing tolls through the motorists' in-vehicle transponder. Operating costs include maintenance and operation of collection equipment, sale or lease of tags, promotion of HOT lanes, and enforcement of the payment of tolls.

Data has indicated that commuters who choose the HOT lanes come from all levels of income. It was believed that only the wealthy would utilize the express lanes because they have the money to afford them but research has shown that this is not always the case. High-income motorists operate approximately 25% of cars in HOT lanes, but the majority of users are low to middle-income motorists. Lower and middle-income motorist may use the HOT lanes periodically when certain circumstances warrant the reliability of being on time.

Although HOT lanes are relatively new to the realm of transportation planning the concept of paying premium pricing for services is not. Airline passengers, for example, expect increased fares during holidays and other high-travel times just as cell-phone users face higher per-minute rates during peak-hour.

5.6.5 Benefits of HOT Lanes[39]

[37] A Guide for HOT Lane Development, Parsons Brinckerhoff with Texas Transportation Institute in partnership with US Department of Transportation Federal Highway Administration publication number FHWA-OP-03-009
[38] Washington DC Region – A HOT Lane Incubator, Innovation Briefs, Volume 15 Number 1, January/February 2004
[39] Ibid

HOT lanes have the potential to afford a variety of benefits to both motorist and transit users. HOT lanes provide an important management tool with the potential to improve travel conditions for a meaningful segment of the driving public with a range of potential benefits as described here:

- ***Trip Time Reliability***: Traffic volumes on HOT lanes are managed to ensure superior, consistent, and reliable travel time, particularly during peak travel periods.
- ***Travel Time Savings***: HOT lanes allow HOV and paying non-HOV motorists to travel at higher speeds than vehicles on congested general-purpose lanes.
- ***Reduced Vehicle Hours Traveled (VHT)***: The addition of HOT options to an existing HOV facility may provide traffic service improvements on congested general-purpose highway lanes. These improvements also have the potential to draw vehicles off of other parallel routes and improve overall flows and speed levels in the corridor.
- ***Revenue Generation***: HOT lanes can provide an additional source of revenue to support transportation improvements such as the construction and operation of the lanes themselves, or to address corridor transit needs or other local-demand management strategies. In areas with funding constraints, certain improvements might not be possible without the additional revenue provided by HOT lanes.
- ***Transit Improvements***: HOT lane revenue may be used to support transit improvements, and new HOT lane facilities provide faster highway trips for transit vehicles.
- ***Enhanced Corridor Mobility***: Improved trip time reliability, higher speeds, travel time savings, and possible transit improvements all lead to greater mobility at the corridor level.
- ***Environmental Advantages***: Compared to general-purpose lanes, HOT lanes may provide environmental advantages by eliminating

greenhouse gases caused by stop-and-go traffic, and by encouraging people to use carpools and mass transit, thereby reducing the number of cars on the road.

- ***Trip Options***: In congested corridors with HOV facilities and transit service, HOT lanes provide SOV motorists with an additional travel choice - the option of paying for a congestion-free, dependable and faster trip.
- ***Utilization of Excess Capacity***: HOT lanes may provide an opportunity to improve the efficiency of existing or newly built HOV lanes by filling "excess capacity" that would not otherwise be used.
- ***New Interest in Managed Lanes***: By increasing the traffic carrying capability of HOV lanes, HOT lanes may make managed lane applications attractive in regions that would not otherwise consider them.
- ***Remedy for Under-Performing HOV Lanes***: In some areas there has been increasing pressure to convert under performing HOV lanes to general-purpose use. HOT lane applications have the potential to increase the number of vehicles traveling on underutilized facilities and possibly reduce pressure to convert them to general-purpose use.
- ***New Interest in Value Pricing***: HOT facilities demonstrate the benefits of value pricing in transportation that may be transferable to a broader array of services.

In California HOT lanes have been in operation since 1996. They have learned from surveys that HOT lanes have:

- A 90% approval rating among users as well as non-users
- Motorist of all income levels use HOT lanes
- HOT lanes generate an annual revenue stream and
- HOT lanes carry nearly 50% of the traffic in peak periods even though they represent only 40% of the freeway capacity (This is so because

traffic in HOT lanes move at 50 to 65 mph, while traffic in general-purpose lanes averages 10 to 20 mph)[40]

6.0 Evaluation Criteria of Alternative Mode Options

The potential applicability of the alternatives to relieve congestion examined in this report is based on comparison of modes and application experience in other parts of the country. However, decision makers make use of evaluation procedures that include:

- Cost-benefit analysis: an important way to determine the feasibility of projects that require a large allocation of resources. Rail transit costs include costs of land-acquisition and system construction and operation. Benefits include attributes such as time savings and operating cost savings.
- Effectiveness analysis: systematic procedure that addresses all non-monetary transportation factors that cannot be quantified in the cost-benefit analysis. It consists of a detailed definition of goals and objectives and the assembly of forecasts, estimates and other analysis results into an evaluation matrix.
- Evaluation of alternatives: required by the U.S.DOT prior to application for federal funds.

The whole project development process includes system planning, alternative analysis, preliminary engineering, final design, and construction. System planning is integrated with the urban transportation planning process conducted by the Metropolitan Planning Agency (MPO). The alternative analysis phase consists of the development of a draft environmental impact statement, selection of the preferred alternative, and

[40]Washington DC Region – A HOT Lane Incubator, Innovation Briefs, Volume 15 Number 1, January/February 2004

elaboration of a funding plan. An important element of this phase is the computation of cost-effectiveness, which is measured by the calculation of the incremental index and/or a user index – it uses consumer surplus as the benefit measure, expressed in terms of user benefits hours. The lower the index is, the better the project.

There have been numerous efforts to create evaluation procedures based on common sense, which would justify the implementation of a specific transit mode. *Table 16* lists measured cities attributes that can be used as determinants of potential modes:

Table 16

Selected Rapid Transit Feasibility Criteria

Criterion	**Desired or Minimum Threshold for System Development**		
	Rail (desired)	**Rail (minimum) or Bus**	**Busway (minimum)**
Urban Area Population	2,000,000	1,000,000	750,000
Central-city* population	700,000	500,000	400,000
Central-city population density (people/mi^2)	14,000	10,000	5,000
CBD floor space (ft^2)	50,000,000	25,000,000	20,000,000
CBD employment	100,000	70,000	50,000
Daily CBD destinations/mi	300,000	150,000	100,000
Daily CBD destinations/corridor	70,000	40,000	30,000
Peak-hour cordon person movements leaving the CBD (four quadrants)	75,000-100,000	50,000-70,000	35,000

* Central City refers to the effective central city, including the central city and contiguously developed areas of comparable density.

Source: Thomas B. Deen and Richard H. Pratt, Evaluating Rapid Transit – Chapter 11 (adapted from Herbert S. Levinson, Crosby L. Adams, and William F. Hoey, Bus Use of Highways: Planning and Design Guidelines, NCHRP Report 155 (Washington, D.C.: Transportation Research Board, 1975), p.26)

Table 17 shows minimum CBD floor-space guidelines for each transit mode and minimum suggested residential densities.

Table 17

Mode	Millions of Square Feet	Minimum Necessary Residential Density	Remarks
Commuter Rail	75	1 to 2 (20 trains a day)	Only to largest downtowns, if rail line exists
Light Rail	35	9	To downtown of 20 to 50 million ft^2 of non-residential floor space
Express Bus	20-50	3 (express bus reached by auto) 15 (express bus reached on foot)	Downtown larger than 20 million ft^2 of non-residential floor space
Local Bus			
10-min service	18	15 (120 buses/day)	Frequent service
30-min service	5-7	7 (40 buses/day) 4 (20buses/day)	Intermediate service Minimum service

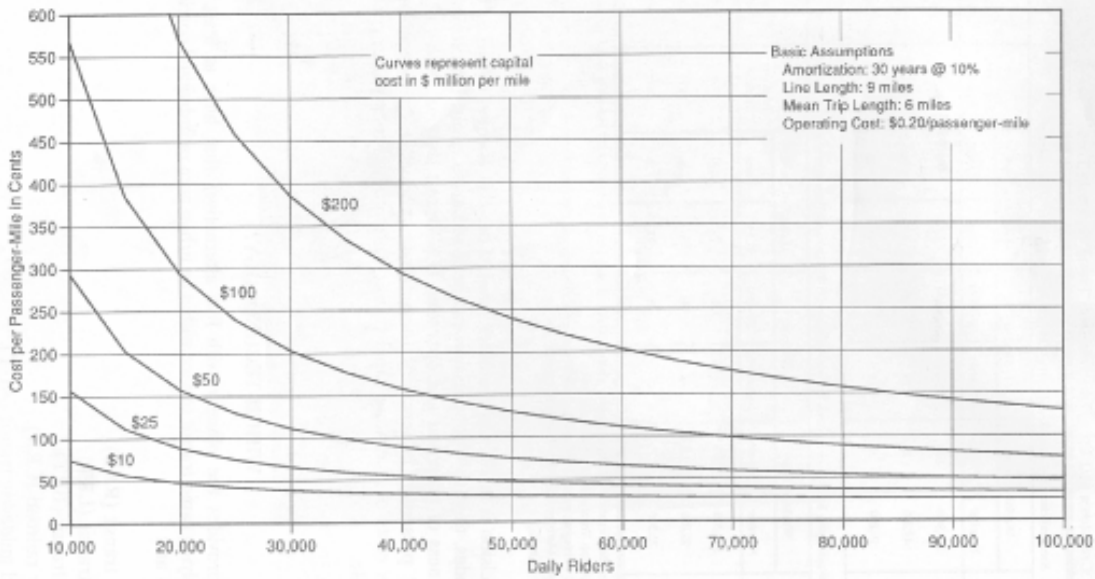
Source: Adapted from Boris S. Pushkarev and Jeffrey M. Zupan, Public Transportation and Land Use Policy, a Regional Plan Association Book (Bloomington, Ind.: Indiana University Press, 1977).

In addition to the aggregate criteria listed on *Table 16* and *Table 17*, city configuration and availability of cheap right-of-way are other major factors that need to be taken into consideration. Bus transit systems benefit from the existing street and highway network and, therefore costs are much less when compared to rail transit. The rail guideways, facilities and stations are fixed and the planning and decision-making process is also more time-consuming and rigorous than other local transit modes.

"*Figure 13* shows the importance of construction costs in determining the total cost of transporting people. It should be noted that the total capital, operating, and maintenance cost of transporting people in automobiles or on the local buses of major cities is in the range of 25 to 50 cents/passenger-mi overall, or 25 to 75 cents/passenger-mi if the upper end of the range is keyed to the incremental cost of new facilities to accommodate commuter travel by auto. From *Fig. 13* it can be seen that 20,000 passengers/day might be all that is required to maintain a 50 cent/passenger-mi cost if a

rapid transit line can be built for $10 million/mi, whereas if capital costs are $100 million/mi, patronage must be 100,000/day to achieve a 75 cent/passenger-mi cost."[41]

Figure 13



* Metric conversion: 1 mi = 1.6 km.

Figure 11-2 *Cost per passenger-mile versus daily patronage. [Source: Compiled by William G. Allen, Jr., for the Transportation Research Board, adapted from report by Alan M. Voorhees & Associates, Inc., A* Long Range View of Transit in Nashville *(McLean, Va.: Alan M. Voorhees & Associates, Inc., September 1970, rev. September 1971).]*

"The all-important issue of physical factors boils down to the bottom-line question of what it is going to cost per passenger-mile to transport people via rapid transit. If this cost exceeds the cost of other options by significant amounts, then any justification offered in terms of overall community benefits must be examined more critically before an affirmative decision is made. On the other hand, if the cost is equal to or less than other existing modes. Then the "go" decision can be made more easily.

[41] *Thomas B. Deen and Richard H. Pratt, Evaluating Rapid Transit – Chapter 11- http://ntl.bts.gov/DOCS/11877/Chapter_11.html , 1992*

Unfortunately, the cost effectiveness of proposed and operating U.S. transit systems, both rail and bus, is often not presented in terms of the ultimate product, a "passenger-mile". *Table 17* shows costs of operating rapid transit systems, both per passenger and per passenger-mile."[42]

Table 17

Costs for Several North American Rapid Transit Systems

	Rail Rapid Transit			Light Rail Transit				Busway	
Item	**Atlanta**	**Baltimore**	**Miami**	**Wash-ington**	**Buffalo**	**Pitts-burgh**	**Port-land**	**San Diego**	**L.A.E1 Monte**
Year of primary data	1987	1987 (b)	1988	1986	1987	1989	1989	1988	1983-86
Annual patronage millions	53.7	11.9	10.4	116.0	8.1	9.0	6.4	8.4	5.7
Daily patronage (thousands)	184.5	42.6	35.4	411.6	29.2	30.6	19.7	27.0	22 (c)
Capital costs millions of 1988 $	2720	1289	1341	7968	722	622	266	176	144
Annual capital costs (millions of 1988 $)	278.1	131.8	137.1	814.8	73.8	63.6	27.2	18.0	8.1 (d)
Annual operating costs (millions of 1988 $)	40.3	21.7	37.5	199.9	11.6	8.1	5.8	7.2	10.9
Total annual costs (millions of 1988 $)	318.4	153.5	174.6	1014.7	85.4	71.7	33.0	25.2	19.0
Cost per passenger-trip (1988 $)	5.93	12.90	16.79	8.75	10.55	7.97	5.16	3.00	3.34
Average trip length (mi) (e)	5.3	3.6<3.6<3.6	7.8	6.2	3.6	6.1	6.1	9.5	7.1 (f)
Cost per passenger-mi($)	1.12	3.58<3.6<3.6	2.15	1.41	2.93	1.31	0.85	0.32	0.47

(a) Includes the cost of purchasing and operating buses (busway portion of affected routes only).
(b) Data does not include Owings Mills extension.
(c) Bus passengers only (does not include carpool/vanpool passengers).
(d) Computed by allocating *55%* of cost to bus operation (in proportion to bus ridership vs. total HOV facility person volume).
(e) Revenue (linked trip) guideway trip length.
(f) Estimated by the authors as a function of line length.

Sources: Compiled by William G. Allen, Jr., for the Transportation Research Board from various sources, including: Don H. Pickrell, *Urban Rail Transit Projects: Forecast Versus Actual Ridership and Costs* (Washington, D.C.: Urban Mass Transportation Administration, 1989); A. D. Biehler, "Exclusive Busways Versus Light Rail Transit: A Comparison of New Fixed-Guideway Systems, in *Light Rail Transit: New*

[42] *Thomas B. Deen and Richard H. Pratt, Evaluating Rapid Transit – Chapter 11- http://ntl.bts.gov/DOCS/11877/Chapter_11.html , 1992*

System Successes at Affordable Prices, Special Report 221 (Washington, D.C.: Transportation Research Board, 1989), pp. 89-97; Texas Transportation Institute, *Transit System Comparison Study–Comparative City Data Base,* Rail Research Project, prepared for the Metropolitan Transit Authority of Harris County (Houston, Tex.: Texas Transportation Institute, August 1989); Crain & Associates, Inc., *The Martin Luther King, Jr., East Busway in Pittsburgh, PA,* prepared for UMTA (Menlo Park, Calif.: Crain & Associates, October 1987); N. D. Lea & Associates, Inc., *Assessment of the San Diego Light Rail System* (Washington, D.C.: N. D. Lea & Associates, November 1983); Samuel L. Zimmerman, "UMTA and Major Investments: Evaluation Process and Results,. in *Transit Administration and Planning Research,* Transportation Research Record 1209 (Washington, D.C.: Transportation Research Board, 1989), pp. 32-36; H. S. Levinson and *others, Bus Use of Highways: State of the Art,* NCHRP Report 143 (Washington, D.C.: Highway Research Board, 1973).

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The table below shows the operating characteristics of each mode. These indicators are based on experience around the United States.

Table 2

Alternative	Uncongested Average Speed	Capital Cost per Mile (Plan, design and construction) (million)	Capacity per Lane Peak-Hour
HOV Lanes	55 mph	$13 to 18	3,450 to 6,000 person-trips
HOT Lanes	55 mph	$15 to 20	3,875 person-trips
Express Bus Service	55 mph	$2 to 3	2,700 person-trips
Light Rail on new track	25-30 mph	$20 to 30	1,920 person-trips
Commuter Rail on new track	35 mph	$20 to 30	3,200 person-trips

Commuter Rail on existing tracks	N/A	$5 to 7	N/A
Light Rail	Up to 65 mph	Average = $ 34.8 M Ranges from $12.4 M to $118.8 M	7,000 to 57,000 riders per day average of 29,000 riders per day

Bus Versus Rail

There has been considerable debate over the relative merits of bus and rail transit (Pascall, 2001; GAO, 2001; Warren and Ryan, 2001). Although rail transit may have greater demand within the area it serves (a greater portion of discretionary riders who live or work there will choose it), bus transit can serve a greater area, and so may attract equal or greater total ridership as rail with comparable resources. However, middle-class voters seem more willing to support funding for rail transit than for bus service, so rail projects may be a more politically feasible option for improving transit service. Much of this debate is based on selective information. Both points can be made depending on the perspectives and case studies that are used. It would be wrong to argue that rail transit projects are always successful and cost effective, but it would be equally wrong to claim that they are always a failure. Some of key differences between bus and rail transit are summarized below. To the degree that rail transit offers better (faster or more comfortable) service, it tends to attract more discretionary riders, but high performance bus service could probably provide similar results (Ben-Akiva and Morikawa, 2002). Rather than a debate between bus and rail, it may be better to consider which is most appropriate in a particular situation. Buses are best serving low- and medium-density corridors. Rail is best serving high-density corridors where historical or current development practices create major centers. Both can become more efficient and effective at achieving transportation improvement goals if implemented with supportive policies that improve service quality, create more supportive land use patterns and encourage ridership.

Bus	**Light Rail**
Flexibility. Bus routes can change and expand when needed. For example, routes can change if a roadway is closed, or if destinations or demand changes.	Greater ridership demand and public preference.
Does not require special facilities. Buses can use existing roadways, and general traffic lanes can be converted into a busway.	Rail tends to attract more discretionary riders than buses within a given catchment area, and voters tend to support more funding for rail than bus-based systems.
Several routes can converge onto one busway,	Greater potential capacity. Rail requires less space

reducing the need for transfers. For example, buses that start at several suburban communities can all use a busway to a city center. As a result, they can have a much greater rider catchment area.	and is more cost effective on high volume routes.
Lower capital costs.	Tends to have a greater positive impact on land use patterns. Tends to create Transit Oriented Development and increase local property values to a greater degree than bus-based systems.
Is used more by people who are transit dependent, so bus service improvements provide greater equity benefits.	Increased user comfort, including larger seats with greater legroom, more space per passenger, and smother acceleration.
	Less air and noise pollution, particularly when electric powered. Bus transfer centers tend to be less pleasant than rail stations.

7.0 Conclusions

In conclusion, the issues of mode choice, information, competition, and funding neutrality should be addressed to in order to have a correctly functioning transportation system in the Tulsa area.

The basic thrust has been a comparative evaluation and a search for the most effective and most responsive mode that can satisfy the transportation needs within an entire community or in any specific corridor.

The planning process to identify what would better suit the region would have to start with an estimation of demand, identification of modes that would respond to the demand, and the evaluation of the advantages and disadvantages of each mode selected.

Once it is selected as the mode that would possibly be most effective to supply the needs of the community or a certain corridor a reliable estimate of patronage and expected revenue is required and how it would help reduce dependence on the automobile. An evaluation of an environmental analysis is also necessary identifying the modes that will have the best effects not only on the air and water but also sociocultural and historical resources and economic performance at the local and regional levels.

This paper describes how to evaluate a public transit policy, program, or change in service. It discusses how transit affects travel patterns, various types of benefits and costs to consider, how to measure these impacts, how to determine whether a particular public transit program is worthwhile, and how to optimize transit services for a particular situation. This analysis framework can also be used to evaluate Ridesharing.

Transit service can provide a variety of different benefits, including *mobility benefits* when it increased travel options, *efficiency benefits* when it replaces automobile travel, *land use benefits* when it results in more efficient and attractive land use patterns, and *economic development benefits* when transit service increases productivity and economic activity. Different types of benefits require different evaluation methods, and some of the most significant benefits are relatively difficult to measure. As a result, conventional planning practices often undervalue public transit, considering just a portion of total potential benefits.

This is not to suggest that public transit is always the best solution to every transport problems. However, it indicates the importance of using comprehensive analysis that takes into account additional factors described in this paper when evaluating transit and comparing it with alternatives. Current transportation planning practices that focus on a limited range of benefits tend to undervalue transit.

Although transit only provides a small portion of total mobility in most regions, it provides a much greater share on high-density urban corridors where transportation problems tend to be greatest, and transit ridership tends to be highest. On these corridors, transit investments are often the most cost effective way to provide mobility, when all costs are considered. Many of the problems and barriers to transit use, such as poor service and low demand by discretionary riders, can be overcome if transit improvements are implemented with complementary TDM strategies.

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