HOUSTON'S TRAVEL RATE IMPROVEMENT PROGRAM

"TOOLBOX" OF IMPROVEMENT STRATEGIES

ADD CAPACITY

Prepared for
Greater Houston Partnership

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ADD CAPACITY

The best known, and probably most frequently used, improvement option is to add capacity to the transportation system. That can mean more traffic lanes, additional buses or new bus routes, new roadways or improved design components.

The strategies listed in this section seek to increase mobility by increasing the capacity of the transportation network. The benefits associated with these improvements include reduced congestion, delay, and travel time. Emissions may be reduced due to the reduction in congestion or may be increased due to the effect of increased demand from new development. The strategies include:

- New Lanes
- New Highways
- Improve Street Continuity
- New Lanes Without Widening the Roadway
- New Toll Roads
- Grade Separation
- Geometric Design
- Managed Lanes/Truck Lanes
- New Streets in New Developments
- HOV Lanes
- Multimodal Transportation Corridor
- Freight Rail Improvements
- Bus Rapid Transit
- Heavy Rail
- Commuter Rail

New Lanes

Implementation	
Hurdles:	All
Level:	Areawide
Sector:	Public
Locations:	Routes

Description

Adding new lanes to existing roads has historically been the most common approach used to alleviate urban congestion. In recent years, some regions have shifted away from capacity increases as a sole strategy for relieving congestion, as it has become apparent that this cannot be the only way to address congestion. In many urban areas, right-of-way is no longer available to widen existing streets or freeways. In other areas, a limited amount of right-of-way is available, but the benefit of additional lanes diminishes as the number of existing lanes on the facility increases. For example, adding one lane to a two lane directional facility provides a 50 percent increase in capacity, while increasing the number of lanes from five to six results in a capacity increase of only 20 percent.

Target Market

While the focus of relieving congestion has broadened to include better management and more efficient use of existing facilities, adding new lanes to existing roads does remain one of the available tools. The addition of new lanes to existing freeways and principal arterials serves to reduce congestion on those routes or alleviate congestion within the surrounding roadway network. Motorist safety may also be improved through the construction of additional capacity in problematic areas. Increases in freeway and arterial capacity, however, may be accompanied by increases in volumes due to vehicles shifting from other routes or times of day to the improved routes.

Benefits and Costs

The costs associated with constructing additional lanes on existing roads vary widely due to right-of-way costs, types of construction materials, roadway design, amount of bridge construction and many other factors. In general, however, the costs associated with freeway expansion are approximately $2 to $4 million per mile per lane. The costs associated with principal arterial street expansion are approximately $0.5 to $1 million per mile per lane. The addition of a lane to expand freeway capacity provides benefit/cost ratios in the range of 3:1, although this can vary significantly. The addition of a lane to expand principal arterial capacity provides benefit/cost ratios near 10:1 (1).

Implementation Issues

Legislation from the Clean Air Act, Intermodal Surface Transportation Efficiency Act and Transportation Efficiency Act for the 21st Century has imposed procedures through which construction projects must be evaluated during the planning phases. Major capital investments are analyzed for a range of alternatives: factors including operation, persons served, mode share, travel costs, and construction and operating costs. This process provides information for public input and participation. An environmental assessment may be required for projects that could have considerable impacts on the environment. For metropolitan areas with air quality problems, projects to widen roadways are subject to an analysis to determine whether the project will result in further degradation of air quality in the region.

1. Henk, R., Poe, C., and Lomax, T. An Assessment of Strategies for Alleviating Urban Congestion, Report FHWA-TX-2-10-90/1-1252, Texas Transportation Institute, Texas A&M University, College Station, TX, November 1991

New Highways

Implementation
Hurdles: All
Level: Areawide
Sector: Public
Locations: Routes

Description

The construction of new highways typically involves construction on newly acquired rights-of-way where no prior roadway existed. The purpose of the new facility may be to reduce congestion on nearby roads, improve safety in the corridor, or provide access to new or future development. New highway construction may also provide the benefit of diverting truck traffic from local streets. In addition to the planning and design of a new highway, issues of acquiring right-of-way and mitigating the negative impacts on the environment and local businesses and residents must be addressed. While building new roads cannot be the only strategy to mitigate congestion, new construction can serve a role in the overall plan to reduce urban congestion.

Target Market

Obtaining local consensus to build a new urban highway can often be difficult. In some areas, groups that feel new highways are not in the best interest of the community may oppose new construction. New highways may be seen to redistribute regional development and encourage single occupant vehicle (SOV) travel. The draw of traffic from other facilities can often leave a new facility congested within a short time after completion. In many areas, new highway construction is occurring in suburban areas as these areas attempt to address congestion problems. There may be less opposition to building new suburban roads where right-of-way is more available at a lower cost, and there are fewer impacts on neighboring development.

Benefits and Costs

The costs associated with constructing new roadways vary widely due to right-of-way costs, types of construction materials, roadway design, amount of bridge construction and many other factors. In general, however, representative costs can be provided. The construction of principal arterials is approximately $1.5 million per mile per lane (1). The construction of “super arterials”—streets with grade-separation at major intersections (see regional thoroughfares)—is approximately $3 to $4 million per mile per lane (2). Finally, the costs associated with new freeway construction are approximately $4.5 million per mile per lane. All of these types of roadway improvements have been shown to produce benefit/cost ratios of 2:1 to 4:1, although the costs and benefits can vary significantly (1).

Implementation Issues

Legislation from the Clean Air Act, Intermodal Surface Transportation Efficiency Act and Transportation Efficiency Act for the 21st Century has imposed procedures through which construction projects must be evaluated during the planning phases. A major investment study may be required in the early planning stages for projects involving federal funding that have substantial costs and a significant impact on capacity, level of service, or mode share within the corridor. This process allows for public input and participation. An environmental assessment may be required for projects that could potentially have considerable impacts on the environment. For areas in non-conformance with air quality standards, projects to build new roadways will be subject to conformity analysis to determine whether the project will result in any further degradation of air quality in the region.

1. Henk, R., Poe, C., and Lomax, T. An Assessment of Strategies for Alleviating Urban Congestion, Report FHWA-TX-2-10-90/1-1252, Texas Transportation Institute, Texas A&M University, College Station, TX, November 1991.
2. 2. Urbanik. T., et al. Considerations in Developing a Strategic Arterial Street System, Research Report 1107-5F, Texas Transportation Institute, Texas A&M University, College Station, TX, November 1990.

Improve Street Continuity

Description

The mobility provided by a roadway system is affected by its street continuity. A lack of continuous streets results from changes in the number of lanes or from inadequate planning for street location between neighboring developments.

Implementation

Hurdles:	Public
Level:	Target Markets
Sector:	Public
Locations:	Routes

Capacity reducing changes in cross section may include reduction in the number of lanes, reduction in lane width, reduction in lateral clearance to obstructions, reduction in median width, reduction in pavement quality, etc. Changes in alignment that affect street continuity include sharp horizontal or vertical curves. These types of curves can limit operating speeds in the vicinity of the facility. Discontinuity can also occur with secondary facilities within the right-of-way, such as bicycle and pedestrian facilities. Bicycle and pedestrian facilities may be disjointed in locations where facilities start and stop without connections to other bicycle/sidewalk facilities in the area.

Target Market

Relatively minor reconstruction projects to upgrade "weak links" of facilities may result in significant increases in mobility for large portions of the facility. A two-lane bridge serving four lanes on either side could be upgraded to a four-lane bridge. Limiting sections of roadway may be upgraded to match the number of lanes of adjoining sections. Sections of roadway that have gaps in bicycle and pedestrian facility networks can be retrofitted to link with existing bicycle/pedestrian facilities. Locations with substandard vertical and/or horizontal alignment for prevailing volumes and speeds can be redesigned. Roadways with reverse curves (a curve in one direction followed immediately by a curve in the reverse direction) can be redesigned with a longer single curve to provide a smoother flow through transitions in roadway alignment. Reconstruction to lengthen existing curves should provide for higher operating speeds, greater sight distance, improved safety, and greater driver comfort, which are important on major urban roadways but may not be as important on minor roadways where speed and capacity are less critical elements.

Implementation Issues

Improvement efforts by METRO, the cities and counties and TxDOT over the last two decades have targeted this problem and completed many of the discontinuous major streets.

New Lanes Without Widening the Roadway

Description

Additional travel lanes may be provided on a road by using one or more shoulders as travel lanes, reducing lane widths, or a combination of the two. Although this practice is typically not seen as a long-term improvement, it may be used as a short-term improvement where bottlenecks exist. Freeway shoulder lanes have been used to provide both general-purpose lanes and high-occupancy vehicle (HOV) lanes. And additional turn lanes have been created at street intersections to improve capacity. Capacity increases of up to 30 percent have been seen on facilities with redesigned lanes (1). One concern associated with converting a shoulder to a travel lane is the impact on safety. Results of studies to assess the safety of converting shoulder lanes to travel lanes have been mixed. Some studies have shown slight increases in accident rates, while other studies have shown either no increase in accident frequency or severity or a slight reduction in accident rates, presumably due to decreased congestion (2,3).

Implementation

Hurdles:	All
Level:	Areawide
Sector:	Public
Locations:	Routes

Target Market

In most cases, the removal of the left shoulder for conversion to a travel lane is preferable from both safety and operations standpoints. Left shoulders are not used as frequently for emergency stops and enforcement as the right shoulder. Regardless of which shoulder is converted, shoulders are often not designed to accommodate traffic loads and the structural integrity of most shoulders may need to be upgraded prior to conversion. In areas with truck restrictions for the left lane, left shoulder lanes will be subject to lower traffic loadings.

While the conversion of a right shoulder to a travel lane is often the easiest to implement, there are several safety and operational disadvantages to converting right shoulders. Right shoulders are commonly used for vehicle refuge during emergency stops or breakdowns and by law enforcement personnel. Other concerns involve entrance ramps, where conversion of a right shoulder would reduce sight distance and potentially adversely affect merging operations. The conversion of both shoulders to travel lanes is not recommended.

Benefits and Costs

The costs associated with implementing shoulder lanes vary depending on the condition of the existing shoulder, however, conversion of a shoulder to a shoulder lane is approximately $1.5 million for construction and engineering and $12,000 per year for maintenance. Shoulder lanes can provide benefit/cost ratios near 7:1, depending on the level of congestion relief and the construction costs (1).

Implementation Issues

Careful planning and design should accompany any consideration of converting a shoulder lane to a travel lane to avoid any potential safety problems such as substandard sight distances. If the facility is on the federal aid system, federal approval will be required in advance of conversion.

Measures that have been taken to mitigate the impacts of shoulder conversion on safety and operations include: advisory and regulatory signing, constructing frequent short parking areas, dynamic message signs, continuous lighting, truck lane-use restrictions, freeway service patrols, and heightened enforcement.

1. A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility, Institute of Transportation Engineers, Washington D.C., 1997.

2. Chen, C. Evaluation of HOV and Shoulder Lane Travel Strategy for I-95, ITE Journal, Institute of Transportation Engineers, Washington D.C., 1995.

3. 3. Curren, J. Use of Shoulders and Narrow Lanes to Increase Freeway Capacity, NCHRP Report 369, Transportation Research Board, Washington D.C., 1995.

New Toll Roads

Description

Implementation
Hurdles: All
Level: Areawide
Sector: Public
Locations: Routes

Toll roads provide an alternative method of financing transportation construction costs. The Harris County Toll roads provided freeway-level capacity many years before public funds would have been available for construction. Since the money for construction of the facility is available at the beginning, efficiencies in contracting can also occur, lowering total costs. Tolls have been used to finance highways, bridges, and tunnels. The users of the facility rather than the general public pay for the construction of the facility, freeing public resources for other uses. Over half of the states in the United States have passed legislation to allow partial or total private investment in roadway construction, which is recouped through user tolls. Interest in toll roads is being spurred further by advancements in electronic toll collection and changes in federal aid policy that now allow some toll projects to be eligible for federal aid.

Many of the negative aspects historically associated with toll roads were related to the standard methods used to collect tolls. The limited capacity of manual toll booths and automatic coin machine booths required expansive toll plazas, as five to six toll booth lanes were required for each general traffic lane to maintain toll road capacity through the plaza. These expansive toll plazas required significant investments in right-of-way and infrastructure costs. Furthermore, these standard toll collection methods incurred high operating and maintenance costs and required motorists to significantly slow.

Target Market

Electronic toll collection technologies have made the construction of toll roads more attractive in recent years. Motorists establish prepaid accounts with most systems and are debited for each toll via an automatic vehicle identification system consisting of tollbooth-mounted antennas, a computer system, and vehicle-mounted transponders. Since tolls can be collected electronically at normal speed, motorists are not delayed and fewer tollbooth lanes are required, reducing required right-of-way, infrastructure, and operating and maintenance costs. Express lanes, which allow payment only by electronic toll collection, provide 2.6 times the capacity of an automatic coin machine tollbooth lane, and 4.1 times the capacity of a manual tollbooth lane (1). Electronic toll collection also makes variable toll pricing feasible as a traffic demand management tool.

There are currently 138 toll bridges, 10 toll tunnels, and 89 toll roads in 31 states within the United States. Approximately 60 percent of these facilities have already implemented electronic toll collection systems. These 237 toll facilities process approximately 4.9 billion annual transactions, representing approximately $5.6 billion in toll revenue (2). Harris County's toll road system cost over $1 billion to construct and handles in excess of 125 million annual transactions generating $217.8 million in revenue.

Implementation Issues

Toll roads can be financed through general obligation bonds, revenue bonds, revenue bonds with supplemented income, private financing, or combinations of sources. A number of public-private partnership models have been developed to finance, construct, and operate toll facilities. In the build-own-operate model, a private organization finances, constructs, owns, and operates the facility. In the build-operate-transfer model, a private organization finances, constructs, and operates the facility for a specified time period collecting the tolls. At the end of the time period, facility ownership is transferred to a governmental agency. In the build-transfer-operate model, a private organization finances and constructs the facility at which time ownership is transferred to the governmental agency. The facility is then leased by the private organization, which operates the facility and collects tolls. In the buy-build-operate model, a private organization buys an existing facility from the government, upgrades the facility, then owns and operates the facility collecting tolls. In the lease-develop-operate model, a private organization leases an existing facility from the government, upgrades the facility, then operates and collects tolls during the period of the lease. Finally, in a temporary privatization model, a private organization takes over operation of an existing facility, upgrades the facility, and collects tolls until the costs plus an agreed upon reasonable rate of return on capital is attained, at which time operations and maintenance revert back to the governmental agency which continuously holds ownership.

1. Analysis of Automatic Vehicle Identification and its Potential Application on the Florida Turnpike: Technical Memorandum 2, Center for Urban Transportation Research, University of South Florida-Tampa, 1990.

2. United States Toll Facilities. Website address: http://www.ettm.com/usafac.html.

Grade Separation

Description

The capacity of roads is limited by the capacity of intersections with other minor or major streets, freeways, or rail lines. When traffic control devices at intersections of two facilities are inadequate to handle approach demand or safety becomes a concern due to frequent accidents, grade separation may provide a solution to eliminate or reduce resulting delay and greatly improve motorist/ pedestrian safety. Grade separation refers to the physical separation of facilities using overpasses or underpasses to eliminate conflicting movements. Grade separations may be used to separate freeway-freeway intersections, freeway-street intersections, street-street intersections, or roadway-pedestrian facility intersections. Grade separations for pedestrians may be warranted to increase pedestrian safety where high volume pedestrian movements exist or where pedestrians encounter high volume or high-speed roadways.

Implementation

Hurdles:	All
Level:	Target Markets
Sector:	Public
Locations:	Sites

Target Market

Grade separation of arterial streets is useful when other strategies such as signal timing improvements and adding turn lanes cannot relieve the congestion and delay incurred at the intersection and where right-of-way limitations prohibit additional through lanes. If congestion is significant only on one street, a typical two-level interchange with a bridge for the through movement of the major arterial may provide the needed capacity. If both directions are experiencing severe congestion, a three-level interchange may be required to provide the desired capacity. Grade separation is also very useful at highway-rail grade crossings to reduce motorist delay and eliminate train/vehicle collisions. Potential accidents are eliminated, trains are able to travel at higher speeds along corridors with grade-separated intersections, and motorists experience no delay due to train crossings.

Benefits and Costs

As an example, the conversion of an at-grade crossing to a grade separated crossing in Austin (due to a high number of fatal collisions) not only eliminated the accident potential, but was estimated to save 28,000 vehicle hours of delay annually. Although the cost of the project was approximately $2.6 million, the project provides an estimated delay reduction benefit of more than $400,000 per year (1). In general, the costs associated with street grade separations are $2 to $6 million per intersection (2).

Implementation Issues

Although grade separation of streets can be costly, dramatic reductions in motorist delay and reduced accident potential can be achieved. The difficulty in finding intersections where land and public approval can be obtained to develop grade separations can be addressed by acquiring more right-of-way for new street corridors, and by targeting especially significant problems in built-up areas. This technique was used in Houston during the 1980s and 1990s by developing a rail-highway intersection priority list; this process should be re-examined and funding targeted for corridors near high-volume railroad lines.

1. A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility, Institute of Transportation Engineers, Washington D.C., 1997.

2. Henk, R., Poe, C., and Lomax, T. An Assessment of Strategies for Alleviating Urban Congestion, Report FHWA-TX-2-10-90/1-1252, Texas Transportation Institute, Texas A&M University, College Station, TX, November 1991.

Geometric Design

Description

Implementation	
Hurdles:	None
Level:	Area
Sector:	Public
Locations:	All

The purpose of geometric design standards for roadways is to provide for safe, efficient, and economical movement of traffic. Design principles taking driver behavior and vehicle/traffic stream performance into account have evolved over the years. The American Association of State Highway and Transportation Officials (AASHTO) has been responsible for developing much of today's design standards. Some of the major areas of geometric design are locational design, alignment design, cross-section design, and access design.

Target Market

The process of selecting the location of a new facility involves input from many groups including engineers, planners, economists, ecologists, sociologists, and politicians as well as the general public. This process considers the location of the roadway from the standpoint of user benefits and economy, but also takes into consideration social, economic (potential for development/redevelopment) and environmental impacts. The actual design of roadways is based on design criteria such as vehicle characteristics (classifications of vehicles, minimum turning radii), vehicle performance (accelerating/decelerating characteristics of vehicle classifications), driver performance characteristics (information handling capabilities, perception/reaction time, and other human factors), and traffic characteristics (traffic volumes, percentage heavy vehicles, design speed).

The elements of roadway design include stopping sight distance, horizontal or vertical alignment, cross-section, and roadside design. Designing for stopping sight distance at every point on a facility with respect to horizontal and vertical alignment provides drivers traveling at the design speed of the facility enough distance to come to a stop if necessary based on such factors as driver perception reaction time, vehicle operating characteristics, pavement conditions, etc. Horizontal alignment elements include degree of curvature and cross-slope to provide for adequate drainage and reduced centrifugal forces in curves. Vertical alignment elements include type of curve (over a hill or in a valley), degree of slope, and length of slope. The vertical design of a facility will determine if provision of climbing lanes or emergency escape ramps are warranted in rural areas.

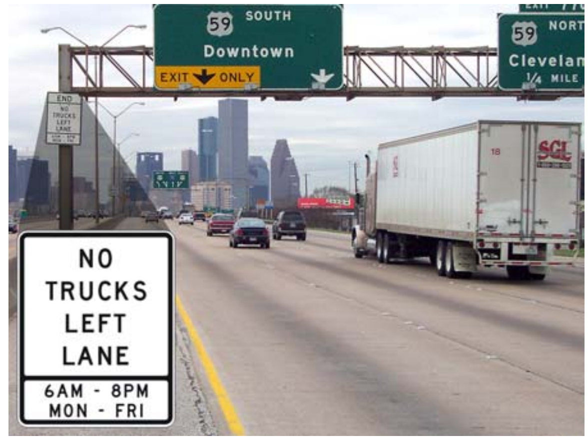
Cross-section design elements include the paved surface, roadside area, traffic separation devices, and provision of bicycle and pedestrian facilities. The design of the paved surfaces includes determining the type of pavement needed to support estimated traffic loads (asphalt or concrete), the number of lanes required to accommodate estimated volumes, the width of the lanes, and type and width of shoulders/curbs. Shoulders are typically used on high-speed facilities, while curbs may be used on lower speed facilities. Shoulders provide a location for vehicle recovery/evasive action, storage for vehicle breakdowns, improved horizontal sight distance, and improved capacity. Curbs are used to provide drainage control, pavement edge/sidewalk delineation, right-of-way reduction, and aesthetics. Roadside area design includes features such as side slopes, horizontal clearance to obstructions, medians, and drainage ditch design. Medians provide for the separation of opposing traffic flows, while traffic separation devices including longitudinal traffic barriers, median barriers, and crash cushions serve to decelerate and redirect errant vehicles from oncoming vehicles or the roadside.

Implementation Issues

Using accepted design standards and principles in the design of roadways will produce higher capacity facilities with improved safety. Studies have shown that substandard design elements such as lanes less than the standard 12 foot width, lateral clearances to obstructions of less than six feet, substandard horizontal/vertical alignment, and inadequate weaving areas result in reduced facility capacity (1). Existing facilities can be upgraded through improvements such as increasing lane width, increasing the lateral clearance to obstructions, straightening alignments, etc., resulting in improved capacity and safety.

1. A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility, Institute of Transportation Engineers, Washington D.C., 1997

Managed Lanes/Truck Lanes



Description

The term managed lanes has recently been used to allow for a more flexible definition of how a lane or group of lanes may operate. The term "managed" implies that the lanes operate under some set of restrictions; however, the restrictions or purpose of the lanes may be varied over time to meet changing needs. One focus of the managed lane concept is to design as much flexibility into the lanes to allow for future changes in the way the lanes are operated. Some of the impetus for the managed lane concept has been the evolution of some high-occupancy vehicle (HOV) lanes to high occupancy toll (HOT) lanes. While each project is typically designed with an initial operating scenario, design considerations for new facilities using the managed lane concept would include assessing the requirements and feasibility of operating the facility in the future as a bus facility, a truck facility, an HOV facility, a tolled facility, or a facility for a combination of users. The provision for heavy vehicle operations (buses and/or trucks), occupancy requirements, tolling capability, and enforcement abilities all affect the design. User combinations or restrictions may be implemented on either a full-time basis or a time of day basis.

Implementation

Hurdles:	All
Level:	Target Markets
Sector:	Public
Locations:	Routes

Target Market

Statewide truck restrictions in Michigan restrict trucks to the right two lanes on roadways with three or more lanes. The implementation was thought to be politically motivated and no studies have been conducted to determine the impact of the restrictions. Trucks have been restricted to the right lane(s) in Georgia except to pass or make a left hand exit. Prior to the restriction, trucks often occupied all freeway lanes prohibiting passing. Truck restrictions were imposed on the Maryland Capital Beltway. Public opinion favors the restrictions; however, the safety impact has not been determined. Truck restrictions were implemented in Illinois in 1964; public support and better operations were cited.

Benefits and Costs

A six-month trial of time of day truck lane restrictions was conducted on I-95 in Broward County, Florida in 1988. The hours of the truck lane restrictions were 7 AM to 7 PM. A review of accidents during the study period showed that overall accidents increased 6.3 percent during the restriction time period, but truck accidents declined 3.3 percent. Four studies have been conducted to assess the impact of truck lane restrictions on the Virginia Capital Beltway. One study was conducted over a two year period, while three other studies were conducted over one year periods. Public and political opinion favor the continuance of the restrictions; however engineering studies recommended removal of the restrictions due to a 13.8 percent increase in accident rate (1).

Implementation Issues

A 1986 FHWA survey of 26 states with truck lane restrictions showed that common reasons for implementation were to improve highway operations (14 states), reduce accidents (8 states), pavement and structural considerations (7 states), and locations with construction zones (5 states) (2). Some of the limitations associated with imposing truck lane restrictions are that they are difficult to enforce, could accelerate pavement deterioration, could increase merging conflicts, and could have limited application in areas with freeway to freeway interchanges due to “must exit” lanes on the side of the mainlanes. In some cases, truck lane restrictions have been implemented with little effort to evaluate their impact.

1. Middleton, D., Fitzpatrick, K., Jasek, D., and Woods, D. Truck Accident Countermeasures on Urban Freeways, Research Report FHWA-RD-92-059, FHWA, U.S. Department of Transportation, Washington D.C., May 1994.
2. Effects of Lane Restrictions for Trucks. Draft Report, FHWA, U.S. Department of Transportation, Washington D.C., June 1986.

New Streets in New Developments

Implementation
Hurdles: All
Level: Target Markets
Sector: Private & Public
Locations: Sites

Description

A functional hierarchy is used in street classification. Major thoroughfares that provide mobility to large volumes of vehicles are arterials. Smaller streets that provide access to houses and shops are collectors and locals. Arterials can further be subdivided into classifications of major arterials and minor arterials.

Target Market

Urban major arterials make up a small percentage of any street system, but serve the highest non-freeway traffic volume corridors. Major activity centers, universities, shopping centers, and special event centers are examples of locations serviced by major arterials. Mobility is provided by the number of lanes and the type of users on the facility and enhanced by the limited access points. Major arterials only make up 5 percent of total street mileage, but carry approximately 50 percent of total traffic volumes. Minor urban arterials connect the major arterials with the collector system. Minor arterials provide slightly less mobility than major arterials, but provide slightly greater access. Minor arterials make up approximately 10 percent of total street mileage and carry approximately 25 percent of traffic volumes.

Collector streets provide mobility around residential, commercial, and industrial areas as well as some land access. Collectors make up a relatively small portion of the total street mileage and operate at lower speeds than arterials. Collector streets connect the arterial street system with the local street system. Collector streets make up approximately10 percent of total street mileage and carry about five percent of traffic volumes. Local streets make up the majority of total street mileage of a city, but serve small volumes of vehicles at slow speeds. Local streets provide low levels of mobility but provide high levels of direct access to residential, commercial, and industrial facilities. Local streets make up approximately 75 percent of total street mileage and carry approximately 20 percent of total traffic volumes.

Implementation Issues

Mobility can be provided in new areas by a street system using the correct mix of functional streets. The function classification of streets is similar to the branching network of a tree. Major arterials provide high levels of capacity to serve high volumes of vehicles at high speeds with very limited access. Each classification down from major arterials (minor arterial, collector, and local) provide successively lower levels of mobility as capacities and speeds become successively lower, but provide successively higher levels of access. Other strategies such as geometric design, urban design elements, intersection improvements, and arterial access management help maximize the mobility of new street systems.

HOV Lanes

Description

HOV lanes are exclusive roadways or lanes designated for high occupancy vehicles, such as buses, vanpools, and carpools. The facilities may operate as HOV lanes full time or only during the peak periods. HOV lanes typically require minimum vehicle occupancy of two or more persons. However, in some locations such as the Katy or Northwest Freeways, occupancy requirements have been raised to preserve the high speeds on the facility. Support facilities such as park and ride lots and transit centers with direct access to the HOV lane are important system elements to increase facility use. HOV lanes may also be used to provide bypass lanes on entrance ramps with ramp meter signals.

Implementation

Hurdles:	Public
Level:	Target Markets
Sector:	Public
Locations:	Routes

Several common types of HOV lanes are barrier separated, concurrent flow, and contra flow lanes.

- Barrier-separated lanes like those that carry more than 87,000 persons daily in Houston are typically constructed in the center of the freeway and physically separated from the general-purpose lanes with concrete barriers. Single lane facilities operate as reversible lanes, flowing in one direction during the morning period and the other direction in the evening period. Multiple lane facilities may either be operated as two-way facilities or reversible facilities.
- Concurrent flow HOV lanes (commonly the inside lane) operate in the same direction of flow as the general-purpose lanes and are usually separated from the general-purpose lanes by a small buffer and wide paint stripe. Dallas' 4 concurrent flow HOV lanes carry more than 88,000 persons each day.
- Contra flow lanes make use of the inside off-peak direction general-purpose lane during the peak period. Movable concrete barriers are used on several facilities around the U.S. including one in Dallas that carries more than 18,000 persons daily. Houston's I-45 contraflow lane, now replaced by a barrier-separated HOV lane, was a pioneer in the late-1970s—plastic posts were the only available separation technique at that time.

Target Market

HOV lanes increase the overall person carrying capacity in a corridor, improve transit service and reliability, and encourage carpool/vanpool formation and bus usage. During the peak rush hours, the six HOV lanes in Houston move the same number of persons as 10 general purpose freeway lanes in each peak direction, equaling 20 lanes of freeway. Successful HOV lanes work best in congested corridors serving major activity centers. The combination of high person demand and slow speeds on the general purpose lanes make buses and carpools more attractive travel options. When combined with parking cost, stress levels, unreliable trip times incurred by solo drivers, HOV lanes can be very successful improvements. Transit usage in Houston corridors with HOV lanes has grown more rapidly than those without HOV lanes. After the implementation of the I-64 HOV lane in Hampton Roads, Virginia in 1992, the freeway experienced an increase of approximately 3,000 person trips with a reduction of over 700 vehicle trips per day (1).

Benefits and Costs

HOV lanes provide significant benefits to transit service. Peak hour bus operating speeds on Houston HOV corridors have increased from 26 mph prior to the HOV lanes to 54 mph with the HOV lanes. The reduction of travel time is estimated to have reduced the required operating time by 31,000 hours and result in a savings of approximately $4.8 million annually. Similar travel time reductions were seen in Pittsburgh on the East Busway where travel times were reduced by 40-50 percent. In Ottawa, Ontario, the transit authority estimates that the busway system has saved the cost of buying 220 regular buses and 40 articulated buses to provide comparable service without the busway system (1).

Studies have shown that HOV lanes increase carpool and transit usage. Of the persons using the I-10 Katy Freeway HOV lane in Houston, 36 percent of carpoolers and 36 percent of bus riders previously drove alone. On the I-395 HOV lane in Northern Virginia, approximately 23 percent of carpoolers and 49 percent of bus riders previously drove alone. On the I-10 San Bernardino HOV lane in Los Angeles, 46 percent of carpoolers and 50 percent of bus riders previously drove alone. On the I-45 HOV Lane in Houston, approximately 39 percent of carpoolers and 39 percent of bus riders previously drove alone (1).

The costs associated with the implementation of HOV lanes are largely dependent on the type of facility. Contraflow lanes cost approximately $3 million per lane mile and can be constructed in 1 to 2 years. Concurrent flow lanes cost approximately $1 to $2 million per lane mile and require 1 to 3 years, depending on the amount of construction. Barrier separated lanes constructed in the center of freeways cost $4 to $6 million per lane mile, while HOV facilities constructed on their own right-of-way can cost $7 to $8 million per lane mile. These are significant projects requiring 2 to 4 years of construction. Additional costs associated with HOV lane systems include construction of support facilities and operations and enforcement costs (2).

The capital costs for constructing the barrier-separated Houston HOV lane system were approximately $8.5 million per mile, including $2.8 million per mile for park and ride lots, park and pool lots, and transit centers, and $300,000 per mile for surveillance, communication, and control systems. Annual costs for operating the Houston HOV lane system are $675,000 ($1995), while annual enforcement costs are $625,000 ($1995). These costs correlate to an average of approximately $260,000 for operations and enforcement per HOV facility per year. Annual operations costs for the movable concrete barrier system used on the East R.L. Thornton HOV lane in Dallas were approximately $600,000, almost equal to the operations costs for the entire 5 corridor Houston HOV system in 1995. Benefit/cost analyses for the Houston and Dallas HOV lanes have yielded results of 8:1 to 48:1, with all cases exceeding the benefit/cost ratio of alternatives with additional mainlanes (3).

Implementation Issues

The primary implementation issue is cost, including costs for the HOV lane, park and ride lots, communication and control systems, and operations and enforcement. Secondary issues involve design considerations when retrofitting existing roads. In both cases, the issues involve federal, state, and local responsibilities.

1. A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility, Institute of Transportation Engineers, Washington D.C., 1997.
2. Henk, R., Poe, C., and Lomax, T. An Assessment of Strategies for Alleviating Urban Congestion, Report FHWA-TX-2-10-90/1-1252, Texas Transportation Institute, Texas A&M University, College Station, TX, November 1991.
3. Henk, R., Morris, D., and Christiansen, D. An Evaluation of High-Occupancy Vehicle Lanes in Texas, 1995. Research Report FHWA/TX-97/1353-4, Texas Transportation Institute, Texas A&M University, College Station, TX, October 1996.

Multimodal Transportation Corridor

Description

A relatively new concept in transportation facility design is the multimodal transportation corridor. Historically, freeways were developed in corridors to provide high volume movement. The concept of a multimodal transportation corridor is that freeways alone may not be the best solution in a given corridor to provide high person movement capacity. Other facilities that may be incorporated into corridor capacity include light rail and designated lanes for buses only, buses or carpools only, trucks only, toll facilities, or combinations of these, in addition to the general-purpose lanes. Transportation demand management strategies may also be considered as part of this process.

Implementation

Hurdles:	Public
Level:	Target Markets
Sector:	Public
Locations:	Routes

Target Market

Multimodal planning requires involvement by a number of constituencies, often including a department of transportation, area transit authority, metropolitan planning organization, community officials and agencies, and various advocacy groups. Advocacy groups may include environmental groups, employers and developers, business associations, etc. Relatively few projects have incorporated the multimodal transportation corridor concept into the preliminary design process. Florida is one of the first states to mandate multimodal transportation corridor design for urban areas with populations over 200,000 persons. Corridors will provide a maximum of six general purpose lanes, four managed lanes, and have a provision for a light rail system to handle future person demand in excess of the capacity of the freeway/managed lane system (1).

Benefits and Costs

Benefits that could be provided from this concept include increased capacity and safety, reduced congestion and travel times, economic development, and environmental quality. The combination of design elements that work best is dependent on the needs and resources of individual communities. The capacity to move large numbers of people is ideal for serving major activity centers. The corridor would be combined with a number of other strategies such as ridesharing programs, parking policies and targeted infrastructure investment.

Implementation Issues

During planning stages of the reconstruction of the I-15 corridor in Salt Lake City, the multimodal alternatives considered with respect to cost and person movement included no build, improved bus service, improved bus service + one highway lane, improved bus service + two highway lanes, reversible HOV lanes, two-way HOV lanes, light rail transit on two tracks, light rail transit on four tracks, light rail transit on two tracks + two highway lanes, or light rail on four tracks + one highway lane. The Maryland Department of Transportation worked with over 50 individual groups during the planning process for the US-301 reconstruction project. The process took a number of years to complete, but resulted in a plan that achieved consensus and resulted in the provision of both highway and transit elements.

1. A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility, Institute of Transportation Engineers, Washington D.C., 1997.

Freight Rail Improvements

Implementation
Hurdles: Local
Level: Target Markets
Sector: Private
Locations: Routes

Description

The presence of highway-rail grade crossings has significant impacts on both rail and automotive traffic. Highway-rail interactions pose accident hazards and operational problems in addition to the safety concern of rail and automotive passengers. Trains blocking intersections during peak periods can result in long queues that may impede flow on surrounding roadways. The resulting queues have a negative impact on vehicle flow, transit service, and emergency vehicle operations. Traffic management of freeway incidents by diversion can be severely impaired by trains crossing a diversion route. Train movement information is still difficult to get at traffic management centers due to communication system differences; these are being worked on but it remains a significant obstacle.

Advancements in technology being used by the railroad industry may also benefit passenger vehicle operations. Identification of railroad cars is accomplished through electronic equipment identification systems utilizing railcar-mounted transponders, railside antenna readers, and computer systems. These systems are equivalent to the automatic vehicle identification systems used by toll roads. Positive train separation uses satellite-based positioning systems to track train location and prevent collisions. Several railroads have developed network operation centers (NOCs). These centers are capable of managing the entire fleet of trains and tracking maintenance vehicles from a central location. Functions of the centers include planning, controlling, and monitoring the flow of trains in the network to optimize service and minimize cost, managing the assignment of locomotives to trains, and providing crew and road operations management.

Other applications of technology to enhance safety and operations are being studied. Railroad crossing monitoring systems could use readers alongside rail lines to determine the position, identification, length, and speeds of trains. This information could be used in conjunction with various information and traffic management strategies. Examples include the placement and operation of dynamic message signs on arterial approaches to at-grade crossings, notifying emergency services of train locations to enable route planning that minimizes response times and notifying transit services to enable changes in scheduling and routing of buses. This information could also be used in conjunction with "smart" intersection controllers that can implement signal timing plans and phase sequences to optimize flow during train crossings.

Operation Respond is a research project designed to improve emergency response to train accidents with hazardous cargo. Software was designed for the program to allow emergency services (police, fire) dispatchers the ability to dial into railroad data centers and access railroad databases to access information on train content and cargo handling. This information can then be relayed to responding personnel to increase the safety and efficiency of the response in much the same way as transit, freeway, and street traffic management centers operate.

Benefits and Costs

Separating highway-rail grade crossings has many benefits with respect to vehicle and rail operations and safety. Potential accidents are eliminated, freight trains are able to travel at higher speeds along corridors with grade separated intersections, and motorists experience no delay due to train crossings. The conversion of an at-grade crossing to a grade separated crossing in Austin not only eliminated the accident potential, but is estimated to save 28,000 vehicle-hours of delay annually. Although the cost of the project was approximately $2.6 million, the project provides a benefit of approximately $435,000 per year in delay savings savings (1).

Implementation Issues

Cost is the major implementation issue to be considered and is, in most cases, a shared responsibility between federal, state, and local governments. Safety issues require close cooperation and involvement with the rail industry.

1. A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility, Institute of Transportation Engineers, Washington D.C., 1997.

Bus Rapid Transit

<u>*Description*</u>

Bus Rapid Transit (BRT) refers to a bus-based system with a separate right-of-way for at least a part of its route. BRT is designed to improve transit travel times, service reliability, and customer convenience and, ultimately, to improve transit ridership. BRT is based on rail transit principles, but instead of the required investment in trains and track, it uses buses and some exclusive facilities integrated with key components of the roadway system. BRT can be characterized by one or more of the following features: exclusive right-of-way at key congestion points or over line-haul segments; improved travel times and service reliability through signal prioritization, bus pull-outs, and automated vehicle location systems that allow real time dispatching; advanced bus technology, which could include quick access, low-floor or multiple door buses to speed boardings and alightings or clean fuel, quick propulsion technologies; faster fare collection to speed boardings, either through the use of prepaid fares or stations designed to separate fare collection from boarding; fewer stops than traditional local transit service, but potentially more stops than park and ride transit; and increased service frequency.

Implementation

Hurdles:	Public
Level:	Target Markets
Sector:	Public
Locations:	Routes

BRT can be applied along an existing freeway through construction of an exclusive bus lane or in combination with high occupancy vehicle (HOV) lanes. There is currently no exclusive busway in North America in a freeway right-of-way. There are, however, many examples of BRT/HOV combinations within freeway right-of-ways, including Houston (North, Northwest, Katy, Southwest, and Gulf Transitways), Washington, D.C. (Shirley Highway and I-66), and Los Angeles (El Monte). These BRT/HOV lanes are used by buses, vanpools, and carpools (of differing occupancy requirements).

BRT can also be built on a separate and exclusive right-of-way, such as a railroad right-of-way. Examples of BRT on a separate and exclusive right-of-way include the busways in Ottawa and Pittsburgh. These busways are used only by buses; vanpools and carpools are not allowed.

Finally, BRT can be built within, along, or even under arterial streets. An arterial street application can range from dedicated lanes of a street (e.g., Lymmo, Orlando's new downtown circulator system or the extensive system in Curitiba, Brazil) to an exclusive bus tunnel (e.g., Seattle).

Off-line BRT bus stops are designed to be away from the busway or HOV lane, and stops are made at off-line, adjacent transit centers or bus stops. The primary advantages of off-line BRT bus stops are provisions for express bus movements when stops are not requested and the feasibility of usage by carpools and vanpools without introducing conflicts with stopping buses.

The primary disadvantages of off-line bus stops are delay to bus riders from the time it takes to exit the busway or HOV lane to reach an off-line station and the space requirements of the off-line stations. The minimum cross-section required (not counting space for off-line stations) would be 36-40 feet. Off-line bus stops are provided for BRT/HOV transitways in Houston and for an exclusive busway in Pittsburgh.

On-line BRT bus stops are located immediately adjacent to the busway, similar to rail stations. Buses stop on the busway for boarding and alighting, and buses cannot pass one another. The primary advantages of on-line BRT stops are minimal delays from stops and minimal right-of-way requirements. The primary disadvantages of the on-line BRT stops are inability of buses to pass one another and infeasibility of allowing use by carpools or vanpools. The minimum cross-section required between stations would be the same as for off-line busways (36 to 40 feet) but a 60 to 70 foot cross-section would be required at stations. On-line bus stops are provided in the Seattle bus tunnel and throughout the Curitiba system.

On-line BRT bus stops with bypass lanes are located immediately adjacent to the busway. Buses stop on the busway for boarding and alighting, but bypass lanes around the stations allow other buses to pass nonstop. On-line BRT bus stops with bypass lanes combine the advantages of the off-line and on-line stations but require additional right-of-way and capital investment to build. Again, between stations, a minimum cross-section of 36 to 40 is required, but the cross section would increase to 60 to 85 feet at stations. On-line bus stops with bypass lanes are provided on the Ottawa busway.

Target Market

The target markets for BRT are congested corridors where transit is already firmly established. The trips carried on BRT are predominantly work trips, since these trips take place during the most congested periods.

Benefits and Costs

The benefits and costs of a BRT system are similar to that of various types of HOV systems. These benefits and costs are discussed in more detail in the HOV lane section of this toolbox. BRT provides significant benefits to transit service, increasing peak hour bus operating speeds similar to HOV applications (see later section). The reduction of travel time provides an incentive for transit use and reduced transit operating costs.

The costs associated with the implementation of BRT are largely dependent on the type of facility. Barrier separated lanes in the center of freeways cost $4 to $6 million per lane mile to build, while BRT facilities in their own right-of-way can cost $7 to $8 million per lane mile to build (including right-of-way costs). These are significant projects requiring 2 to 4 years of construction (1).

The capital costs for constructing the barrier-separated Houston HOV lane system were approximately $8.5 million per mile, including $2.8 million per mile for park and ride lots, park and pool lots, and transit centers, and $300,000 per mile for surveillance, communication, and control equipment. Annual costs for operating the Houston HOV lane system are $675,000 ($1995), while annual enforcement costs are $625,000 ($1995). These costs correlate to an average of approximately $260,000 for operations and enforcement per HOV facility per year (2).

Implementation Issues

If existing HOV lanes and off-line BRT bus stops are used, there are few significant cost issues involved. Implementation issues are primarily associated with bus/line management. Additional BRT lines may well require the addition of new stops and/or new HOV lanes that would involve potentially significant costs. In the later case, federal and state, in addition to local funds, could be involved.

1. Henk, R., Poe, C., and Lomax, T. An Assessment of Strategies for Alleviating Urban Congestion, Report FHWA-TX-2-10-90/1-1252, Texas Transportation Institute, Texas A&M University, College Station, TX, November 1991.
2. Henk, R., Morris, D., and Christiansen, D. An Evaluation of High-Occupancy Vehicle Lanes in Texas, 1995. Research Report FHWA/TX-97/1353-4, Texas Transportation Institute, Texas A&M University, College Station, TX, October 1996.

Heavy Rail

Implementation
Hurdles: Public
Level: Target Markets
Sector: Public
Locations: Routes

Description

Heavy rail systems are most suitable for corridors with high-density office developments and some medium density residential high-density areas with a high level of nonresidential development. Heavy rail systems provide high speed/high capacity service, but at a high cost due to the required exclusive right-of-way (with no at-grade crossings) and high cost of vehicles. Long trains of six to ten cars, third rail power supply, high passenger loading platforms, high degree of automation, and sophisticated signaling are all associated with heavy rail. The capacity of heavy rail train lines is a function of car size, seating arrangements, door configuration, number of cars in the train, number of allowable standees, and minimum headways. Minimum headways are dependent on dwell times at stations, train lengths, acceleration and deceleration rates, train control systems, and track arrangements. A number of systems around the world operate up to 30 trains per hour during peak periods with headways of two to three minutes moving 15,000 to 80,000 passengers per hour in the peak direction (1). In general, costs associated with development of heavy rail transit are approximately $80 to $100 million per mile (2).

Target Market

Historically, heavy rail systems have been implemented in high-density urban areas where both origins and destinations can be served Policies and programs to increase the population and employment in the areas immediately adjacent to rail stations are also important to encouraging walk trips to/from the rail stations.

1. Transportation Planning Handbook, Institute of Transportation Engineers, Washington D.C., 1992.
2. Henk, R., Poe, C., and Lomax, T. An Assessment of Strategies for Alleviating Urban Congestion, Report FHWA-TX-2-10-90/1-1252, Texas Transportation Institute, Texas A&M University, College Station, TX, November 1991.

Commuter Rail

Source: Dallas Area Rapid Transit

Implementation
Hurdles: Public
Level: Target Markets
Sector: Public
Locations: Routes

Description

Commuter rail systems generally operate between suburban areas and urban centers providing high-speed service between stations with single or multiple car passenger trains. Because commuter rail typically uses existing rail right-of-ways—either with the construction of new tracks adjacent to the freight rail tracks or by upgrading the freight rail tracks—it is can be less costly and faster to implement than rail systems requiring new or exclusive right-of-way.

Commuter rail service is most common in high-volume congested corridors, operating for many years in large cities in the Northeast and Midwest U.S. and in Canada. More recent commuter rail operations have begun in California, Texas, Florida, and Washington. In general, costs associated with the development of commuter rail transit are approximately $5 to $10 million per mile (1).

The Trinity Express commuter rail services the 27-mile line between Union Station in Downtown Dallas and Richland Hills in northeast Tarrant County with stops at five intermediate stations. An extension of the line into downtown Ft. Worth is scheduled to open in Fall 2001. Service from Union Station to Richland Hills is available during peak periods only Monday through Friday, while service from Union Station to DFW Airport is available Monday through Saturday from 6 AM to 11:30 PM. Travel from Union Station to Richland Hills takes approximately 45 minutes, while travel from Union Station to DFW Airport takes approximately 30 minutes. The Trinity Express operates on approximately 30 minute headways between Union Station and DFW Airport on weekdays and one hour headways on Saturdays. Trinity Express tickets may be used for free transfers to bus, light rail, or DFW Airport shuttles. Customers may park for free at several Trinity Express stations or any of the DART light rail stations then transfer free to the Trinity Express. The Trinity Express uses both self-propelled diesel rail cars and double decked passenger coaches powered by locomotives.

Target Market

A number of comparisons have been made between the characteristics associated with cities with light rail systems and those with commuter rail. Most of these differences can be explained by the differences in developments and travel markets that they serve. Commuter rail travel times are 50 percent greater and distances 200 percent longer than those with light rail. The average spacing of stations is approximately two miles for commuter rail and a half-mile for light rail. Approximately 90 percent of commuter rail stations have significant parking, while only one-third of light rail stations have significant parking. The population density within two miles of commuter rail station is 1.8 persons per acre, while the density around light rail stations is 4.5 persons per acre (2).

In locations where commuter rail is being implemented in lower density areas, it is important to have adequate support facilities such as park and ride lots and bus service to and from rail stations.

1. Henk, R., Poe, C., and Lomax, T. An Assessment of Strategies for Alleviating Urban Congestion, Report FHWA-TX-2-10-90/1-1252, Texas Transportation Institute, Texas A&M University, College Station, TX, November 1991.

2. Parsons Brinckerhoff Quade and Douglas. Transit and Urban Form, Transit Cooperative Research Program Report 16, Transportation Research Board, Washington D.C., August 1996.