Review of Research on Controlling the Level of Service on Urban Freeways

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This paper presents a review of the research and implementation of traffic control systems in Texas. The magnitude of the problem is illustrated through data from freeways with the heaviest traffic flow in Texas. Systems that both control the level of service and only improve the level of service are discussed. Several approaches to entrance and exit ramp control are reviewed, and the entrance and exit advantages and disadvantages are discussed. Control of freeway demand is outlined in terms of the problems of operation and implementation and the advantages of the control. The methods and procedures for improving the level of service of operation on urban freeways broaden the scope of the paper to include geometric expansion of the roadway, detection and removal of capacity-reducing incidents, and improvement of vehicle occupancy rates. All of these methods are directly affected by the availability and use of traffic surveillance, control, and motorist communications systems.

A goal of the research and implementation program in Texas is to control the level at which a freeway will operate, but the scope of this paper is broadened to include those systems, procedures, and physical changes in the freeways that are implemented simply to improve the level of service, for they are a part of the procedure for gaining control of a freeway so that desired levels of service can be achieved.

This paper is directed principally toward the work that the cities and the Texas Highway Department are doing in conjunction with the research program of the Texas Transportation Institute.

Texas is fortunate to have a well-developed urban freeway system. The parallel service roads and the arterial street system in most instances provide adequate capacity for urban traffic demands. Traffic congestion, for the most part, is of short duration. This is not to say that there are no problems nor that the urban transportation problem is solved for the next 10 years. Rather, the situation is that there is room to grow with proper planning and control. There is time to develop other forms of public transportation that will be needed. Texas has a very fine foundation on which to build an urban transportation system.

MAGNITUDE OF THE TRAFFIC PROBLEM

The magnitude of the freeway problem in Texas today is illustrated by statistics

Table 1. Traffic problem on urban freeways in Houston.

Site	ADT	Traffic Flow	Time		Percentage of Traffic
			Minutes	Percent	
1	170,000	Free	16¼	68	51
		Heavy[a]	5	20	25
		Congested[b]	2¾	12	24
2	130,000	Free	15	64	34
		Heavy	8	33	58
		Congested	1	4	8

[a]1,500 vehicles/lane/hour. [b]Speed reduced to below 40 mph.

given in Table 1 from the Houston-Galveston Regional Transportation Study for the urban freeways of Houston. The table shows the percentage of time that the most critical freeway sections in Texas experience congestion.

During the peak period, 24 percent of the traffic experiences congestion and an additional 25 percent is in heavy traffic at site 1. If only 2 percent of the peak-period congested traffic is diverted and if strict control of traffic flow can be maintained, then no traffic will experience congestion and 47 percent will be in heavy traffic flow conditions.

If the control is much stricter so that 25 percent of the peak-period heavy plus congested traffic is diverted and if strict control of traffic flow can be maintained, no traffic will experience congestion and no traffic will experience heavy traffic flow.

How could 25 percent of the peak-period traffic be diverted?

1. Divert truck traffic, which is 1 to 2 percent of the traffic.
2. Increase the car pooling rate from the present 1.3 to the desired 1.45. This would produce a 10 percent reduction of vehicles and no change in person volume.
3. Use control to divert 750 vehicles per hour, which would produce a 10 percent reduction.
4. Increase ridership on buses from 150 to 375 passengers per hour—a reduction of 2 to 5 percent (no change in person volume).
5. Try other methods.

These methods would yield a total diversion of 25 percent of the vehicles but only 10 to 12 percent diversion of persons.

MEASURES TO CONTROL LEVEL OF SERVICE

Some of the measures taken in Texas to reduce or eliminate traffic congestion on urban freeways and to control the level of service provided the motorists are discussed below.

Ramp Metering

Now into its second decade, ramp metering continues to offer benefits to urban freeway operations by increasing efficiency and reducing accidents. It has been the experience in Texas that ramp metering alone cannot control the level of service. It delays the development of congestion, shortens the length of congestion, reduces overall travel time, and reduces accident experience and the resultant costs of property damage and delays. It establishes a proper travel pattern for existing conditions. It may, in some instances, actually eliminate traffic congestion, but often congestion continues because

1. Control strategies often have optimum throughput as a goal, which depends on exit volume demands that are not controlled;

2. There are ramp control overrides, such as queue length and maximum waiting time, that must be accommodated; or
3. There are ramp demands that must be accommodated, regardless of freeway conditions.

Even so, ramp metering continues to be a very cost-effective control system.

Closure of Entrance Ramps

Experiments and studies on the effects of ramp closures have been conducted many times during the last 15 years. They have proved that entrance-ramp closures improve the level of service more than metering does, but they can only be used when good alternate routes are available and when the political consequences are favorable.

Ramp closure may not be so efficient as metering in improving overall traffic operations if it is not responsive to changing traffic conditions on freeways and arterials. Ramp closures do have the advantage of providing priority control to buses and perhaps car pools.

Ramp closures should be considered as a part of a ramp control program, in combination with ramp metering where possible.

Closure of Exit Ramps

On occasions, exit-ramp closures can be used to improve freeway operations. Permanent closure is the most acceptable from an operational view, but, because of access rights established over the years, it may not be possible. Relocation of ramps as part of a betterment program is being used successfully in Houston.

Real-time control of exit ramps has been tested in Dallas and shown to be effective. In the North Central Expressway corridor, there are adequate alternate routes adjacent to the freeway to provide a bypass to critical bottlenecks. Closing exits just downstream of the bottleneck caused a new traffic pattern to develop in which large volumes exited the freeway upstream of the bottleneck.

Methods of operating the ramp closure are still a problem, and so manual closure was used in the tests.

On-Freeway Control

The last element of urban freeway traffic to be controlled is the on-freeway traffic, i.e., main-lane traffic. This concept has been tested on special controlled-access facilities such as tunnels, bridges, and, to a certain extent, toll roads.

Texas is currently trying to control traffic demand with traffic signals to reduce the density of traffic downstream. At this time, there are many more questions than answers, which means considerable study and testing remain to be done. The basic question is, can this type of control be applied to urban freeways in a safe and efficient manner? This same question was being asked several years ago when ramp metering was being developed.

Questions

1. Can the control be operated safely?
2. Will the control be recognized by motorists as a valid control measure?
3. Will on-freeway control be effective in achieving the desired objective?
4. Can it be applied to all urban freeways?

In answer to question 1, there is no other way that it will be done. If advanced signals, signs, markings, and so on cannot provide reasonable assurance of safe operation, then the control should not be used.

With regard to motorists, adequate design with strict enforcement will be necessary. The same is true of other unique control measures such as ramp metering and lane assignment to car pools.

Question 3 is the easiest to answer. Texas has conducted both theoretical and field simulations of this type of operation, and data have been collected that support this type of control.

As with ramp metering, each freeway has different operational characteristics that must be considered in the design and operation of a control system. Careful consideration must be given to the first test site for this control. Only after experience in acceptance by the public and the operational achievements of the control has been obtained can question 4 be answered.

Objectives

The purpose of on-freeway controls is to control traffic demand so that, on the freeway lanes downstream of this location, a desired level of service can be maintained. This desired or designed level of service may be set to maximize throughput of a downstream bottleneck; it may be set to provide a high level of service to all vehicles downstream of the control site, particularly buses and car pools that enter from nearby park-and-ride terminals; it may be set to distribute total delay in a more equitable manner, with some freeway capacity being saved for downstream entrance ramps; or it may be set to encourage diversion from the freeway because of normal traffic congestion or because of capacity-reducing incidents.

Problems of implementation

As with any new type of control system, there will be problems in implementing the traffic signals. First, all operating agencies at the local level must approve the control. The policing agency must be convinced that the signal is enforceable. The state and federal agencies that fund and install the system must be convinced that it is a proper application of traffic control principles. Finally, a suitable test site that has the highest probability of success must be located.

Alternatives

Following are some of the alternatives to total freeway control that allow control of traffic demand to achieve desired levels of service.

1. Ramp metering—Generally, ramp metering cannot achieve the necessary level of control to reduce freeway densities that have increased above a critical level.
2. Ramp closure—Closing a ramp is more effective than ramp metering, but may be impractical because of the lack of alternate routes or political considerations.
3. Lane closure—Lane closure has been used to provide a transition to reversible flow, to balance merge and capacity with demand, to improve merge area operations, and to warn motorists in advance of lane blockage. The use of lane closure to control demand on the main lanes of the freeway has not been tested. Merging one lane of traffic into adjacent lanes that will be congested is difficult.
4. Lane assignment—Reserving a lane for buses or car pools or both could have the effect of reducing the input to a downstream roadway section. It is less restrictive than lane closure, but has the same drawback in operation and is an enforcement problem.
5. Speed control—It has been suggested that strict approach-speed control could reduce demand. This has not been very effective on urban freeways when motorists have been requested to do so voluntarily. Speed control into tunnels or bridges is more effective.

Advantages

Control of all freeway lanes by a standard traffic signal should be much easier to enforce than lane closure, lane assignment, and speed control. Also, motorists should understand what is expected of them.

On-freeway control should require minimum time inasmuch as the control directly affects flows on the order of 100 to 130 vehicles per minute. This type of control would also probably be less expensive than any of the alternatives.

On-freeway control could be further enhanced by the application of lane assignment upstream of the control site. That is, a lane reserved for buses or car pools could move through the freeway signal with little or no delay.

MEASURES TO IMPROVE LEVEL OF SERVICE

This paper has concentrated on the subject of on-freeway control because it provides the opportunity to close the loop on the freeway control system and to apply the principle of control of level of service.

There are other activities under way in Texas that apply more to improvement of level of service.

Expansion of Roadway

Temporary or permanent expansion of the roadway is always an excellent approach to solving a capacity-demand problem. However, the addition of a new lane to a freeway may be financially or physically impractical.

The temporary use of a roadway shoulder as another travel lane has been practiced for several years, but often this approach has been rejected because shoulders are not continuous over bridges. After freeways are constructed, traffic patterns change. The use of the shoulder over short sections of freeway may prove very beneficial in relieving a bottleneck section. Further expansion of the roadway may permit the return of the shoulder to the use of an emergency lane.

The same consideration is being made in the merging areas of major interchanges. The use of the shoulder for travel can move the point of merge some distance from the interchange and reduce the conflicts caused by sight restrictions. The improvement in accident experience is expected to be significant.

Detection and Removal of Disabled Vehicles

Maintaining existing capacity is most important. The management of traffic incidents is one area that requires more emphasis in terms of controlling level of service, for one minor incident can render all control systems, priority systems, or expansion systems useless.

Texas is promoting the use of service patrols in an attempt to define what is cost-effective and how to best use the few vehicles that are made available for this function.

The research program is investigating electronic systems for detecting incidents at low and high volumes. The highway department has taken the positive research results in the Accident Investigation Site (AIS) system and is promoting AIS procedures that do not require expensive capital investments, but do require cooperation and involvement of the policing agencies. Time spent on accident reports at or near the scene of the accident is too long and affects both directions of traffic flow. The provision of a parking area out of sight of freeway traffic can be accomplished by new construction on freeway rights-of-way or on adjacent streets and parking lots.

Assignment of Facilities to High-Occupancy Vehicles

One method of controlling on-freeway traffic demand is the use of lane assignment

for high-occupancy vehicles. Its application to the control of the level of service should be examined.

If a freeway lane is taken away from general use and assigned to buses and car pools, the remaining lanes will in most instances operate very poorly at a lower level of service. If the reserved section of the lane is relatively short, compared to the average trip length, and if the reserved lane reduces demand to the downstream section and causes all lanes to operate at a high level of service, the overall level of service may be improved. If the served lane is added to the direction of flow (either new construction or counterflow operation), the level of service of the other lanes is improved by a reduction in demand and elimination of buses.

The approach in Texas has been to improve bus operations by improving operations of all vehicles on the facility where possible, but priority (lane bypass, entrance ramp, signal preemptions) has been provided, where necessary, at the expense of passenger vehicles. In Dallas, entrance ramps are closed to all vehicles except buses, some ramps have a bypass lane, and the traffic signal at intersections is preempted by approaching buses.

In addition, consideration is being given to the assignment of a freeway lane upstream of the control station.

Improvement of Vehicle Occupancy Rates

Reducing vehicle demand by increasing bus and car pool use relates directly to the control measures mentioned. The computer matching activity is being promoted by cities in Texas as elsewhere in the United States. Incentives other than improved level of service are also being offered.

CONCLUSIONS

The basic control systems and procedures for improving and controlling the level of service on urban freeways have been or are now being tested. Implementation of proven systems has taken longer than expected because of the need for an agency to operate the systems. Also, there are many agencies and jurisdictions involved in urban traffic that must be coordinated.

Finally, it is important to realize that in most areas urban freeways are considered the backbone of the public transit system and the surveillance and control systems that are being developed are of greater importance when the public transportation vehicles are considered.

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