AN INVESTIGATION OF POSSIBLE SOLUTIONS TO THE CONGESTION CYCLE

by

Ingrid Anderson

Professional Mentor

David Roper

Roper and Associates, Inc.

CVEN 689

Transportation Information and Control Systems Design

Department of Civil Engineering

Texas A&M University

College Station, Texas

August 1992

SUMMARY

A growing concern in most urban areas is traffic congestion. Traditional methods of alleviating congestion have included building more capacity and encouraging motorists to participate in ridesharing programs. These solutions are limited, however, because the resulting improvements in traffic flow deteriorate with the arrival of new demand. Demand increases because motorists who would otherwise be using alternative routes or modes of transportation decide to switch to a freeway whose traffic flow has improved. A more effective solution, therefore, may involve the use of positive controls.

Positive controls differ from voluntary demand management programs in that they are imposed on motorists by an agency. Various types of positive controls have proven to be effective in improving traffic operations. Some examples of positive controls include ramp metering, ramp closure, and freeway-to-freeway metering.

Ramp metering has provided considerable improvements in traffic operations in several cities. For example, most ramp metering systems have resulted in increased speeds, increased volumes, and decreased travel times.

Although ramp closure has not been implemented as frequently as ramp metering, it shows significant potential in alleviating congestion at bottlenecks. Shifting the demand upstream of a bottleneck to a ramp downstream, improves freeway traffic flow.

The third type of ramp control, freeway-to-freeway metering, is probably the least developed. Although only a few cities have taken the initiative to meter a freeway connector, experience with freeway-to-freeway metering has been successful.

Staggered work hours programs can also serve as a type of control. The goal of these programs is to stagger peak period demand over a longer period of time. They act as a type of control because, when implemented, participating employees are required to be at work at their scheduled starting time. Evaluations of staggered work hours programs have demonstrated that they can be very effective in flattening out the peak travel demand distribution.

A potential limitation with each of these types of controls is a lack of public acceptance. In order for the public to be supportive of any enforced control, they must understand the need for that control. A public education campaign would explain to the public the need for positive controls and would contribute to the success of such controls.

TABLE OF CONTENTS

INTRODUCTION

Congestion continues to be a major problem in many urban areas. Congestion occurs when traffic demand exceeds capacity. This occurs most frequently and consistently during peak periods. In fact, the traffic demand on urban freeways during the peak hours is typically twice the average hourly demand (1). Traditionally, the congestion problem has been handled by building more capacity. Today, circumstances make the addition of capacity an unsuitable method of alleviating congestion. First of all, provisions in the 1990 Clean Air Act Amendments limit the addition of capacity in some metropolitan areas. Second, adding capacity is not always feasible. "In high density urban areas, expanding roadways to handle ever-higher traffic volumes can run into problems such as exorbitantly expensive right-of-way, no available right-of-way at all and community opposition to expansion" (2). Another problem with adding capacity is that, given time, the new capacity is filled with more demand, causing the freeway to return to congestion. Thus, a type of "congestion cycle" develops: congestion exists, improvements are made, traffic flow improves, traffic volumes increase, congestion returns.

How can the cycle be broken? One strategy is to operate the roadway more efficiently. This can be accomplished either through voluntary demand management strategies or through positive controls. The limitation with voluntary traffic demand management strategies, however, is that their participation is related to traffic flow conditions. That is, a motorist finds little reason to carpool or to take public transit if the freeway appears to be flowing smoothly. Therefore, when the freeway is uncongested, a motorist is likely to return to commuting in his own vehicle. If too many commuters take similar steps, the freeway returns to congestion. Positive controls can be effective in preventing this return to congestion. For example, if a freeway *appears* to be flowing smoothly, while it is actually near break down, positive controls can be used to prevent additional demand from entering the freeway.

Purpose of Paper

The purpose of this paper is to identify and investigate various positive controls which could help maintain the traffic flow on a freeway. The paper begins by confirming that the congestion cycle actually exists. Several examples around the country are identified. Four types of positive controls are then described and evaluated: ramp metering, ramp closure, freeway-to-freeway metering, and staggered work hours. The paper concludes with possible methods of educating the public about the congestion cycle and the importance of controls.

Scope

Although the congestion cycle likely occurs on arterials as well, the scope of this paper is limited to urban freeways. This paper is intended to provide an overview of possible solutions to the congestion cycle. It is not intended to provide a detailed methodology for implementing the solutions. The content of this paper is based on a review of available literature, case studies, and telephone interviews with representatives from several transportation agencies.

EXAMPLES OF THE CONGESTION CYCLE

Before discussing possible solutions to the congestion cycle, it was considered necessary to verify its existence. Transportation professionals in three cities were asked to identify a situation where congestion had returned following an improvement in freeway traffic flow. Their responses are summarized below.

Waukesha, Wisconsin

In an interview with Ron Sonntag (3), two situations were identified. In both cases, the freeway returned to congestion after an extended period of time.

In the first case, a major central interchange was built in 1968 which connected the legs of three freeways. Immediately, there was considerable congestion due to excessive ramp volumes upstream of the interchange and a bottleneck downstream of the interchange. A year later, ramp metering was installed upstream of the interchange to alleviate some of the congestion. This improved the traffic flow for 3 to 4 years. In addition, the downstream bottleneck was removed by adding a lane. This improved traffic flows for about 10 years. The eventual deterioration of traffic flow was attributed to overall traffic growth and changing traffic patterns.

In the second case, left merges consisting of two lanes were restriped as single lane left merges. This was done in the late 1960s. Soon after the restriping was completed, ramp metering was installed. Traffic flows did not deteriorate until the late 1970s. Again, the deterioration was attributed to basic traffic growth over a long period of time.

Public reaction and acceptance to ramp metering was good back when it was installed. Recently, however, there has been more of a problem with political resistance from officials. This is mainly due to potential backlash from the public. In general, the public officials are currently resistant to and fearful of change.

Denver, Colorado

Louis Lipp (4) gave an example of two freeways, I-25 and I-225, which were restriped in the mid-70s to accommodate an additional lane. In both cases the shoulders were virtually eliminated. Only two to three months elapsed before congestion returned to the same level as before. The estimated percent increase in traffic volume was 26% (from 5800 vph to 7300 vph during peak hour). The main cause of the returning congestion was a shift in both route and time of travel. The shift in route occurred because people who previously used parallel arterials began to use the freeway. The shift in time occurred because people shifted to their desired time of travel.

Ramp metering was installed to alleviate the congestion on I-225. It resulted in a slight increase in capacity. The ramp metering system was not met with much opposition either. In fact, the public reaction/acceptance to ramp metering has been very good in the Denver area so far.

Minneapolis, Minnesota

The example provided by Glen Carlson (5) involved a ten-mile stretch of I-94, between Minneapolis and St. Paul, where the number of lanes varied between 2 and 3 lanes. The capacity of the entire section was limited by the 2-lane sections. To increase the capacity, the right shoulder in the 2-lane sections was utilized to make the entire section 3 lanes. This was completed in 1990. In four to six months, however, the freeway was running at capacity again. The estimated increase in traffic volumes was the capacity of a single lane (1800 vph). A large latent demand from motorists using other routes was identified as the main cause.

While the shoulder was being converted to a third lane, ramp metering was installed on the freeway. The metering rates have become about as restrictive as they can be without causing queues to back up into the arterial streets. While the metering rates are restrictive, there has not been a problem with public acceptance.

BREAKING THE CONGESTION CYCLE

In order to break the congestion cycle, two problems need to be solved. The first is that motorists are willing to accept a certain amount of congestion. For instance, motorists will continue to enter a freeway which is already operating at capacity, thereby causing it to break down. This results in a less efficient operation of the freeway. Therefore, if the demand on the freeway can be prevented from exceeding capacity, the freeway will continue to operate more efficiently, breakdown should not occur, and the congestion cycle will be broken.

Positive controls, such as ramp metering, ramp closure, freeway-to-freeway metering, and staggered work hours can help prevent the demand from exceeding the capacity of a freeway. The most effective way to use positive controls is to implement them at the same time that a freeway improvement is made. For example, ramp metering should be installed right after capacity is added to a freeway. This would help prevent additional demand from causing the freeway to return to congestion. If positive controls are not implemented until much later, after congestion has returned, they may be less effective. Furthermore, public acceptance may not be as great as it would be if the controls were implemented at the time the improvement was made.

The second problem which needs to be solved is that the public does not understand how sensitive freeway traffic flow is. They do not understand how easily a smoothly flowing freeway can break down. Positive controls will not be able to entirely break the congestion cycle unless the attitudes and behavior of the general public can be changed. Therefore, the last part of this paper addresses the need for a massive public education campaign.

TYPES OF POSITIVE CONTROLS

Ramp Metering

When a freeway appears to be running smoothly, it may actually be operating at or near capacity. In fact, any minor disturbance could cause the freeway to break down. One such minor disturbance is that caused by vehicles entering or exiting via ramps. When vehicles are required to change lanes in order to enter or exit a freeway, they cause turbulence in the traffic flow. This results in inefficient operation of that section of the freeway (6). This turbulence and reduced capacity can ultimately lead to prolonged congestion.

Ramp metering can play an important role in preventing the turbulence caused by entering vehicles. By controlling the rate at which vehicles enter the freeway, ramp metering provides a way for ramp and mainline traffic to blend more efficiently and with less turbulence (7). Although ramp traffic experiences additional delays, the mainline capacity is protected and the overall operational efficiency of the freeway is improved. In some cases, mainline capacities have even increased as a result of ramp metering (8). Ramp metering "has proven to be one of the most cost-effective techniques for improving traffic flow on freeways"(9). Another function of ramp metering is to regulate the amount of demand permitted to enter the freeway. In this way, ramp metering can help prevent the demand from exceeding capacity on the freeway. In this section, three different types of ramp metering will be described, and the benefits achieved by ramp metering in various cities will be summarized.

Types

Ramp metering can be operated in three different ways. The type of operation chosen depends on the needs of a particular freeway. The three methods are:

- Fixed-time operation
- Traffic-responsive operation
- System or integrated control

<u>Fixed-time Operation</u>

A fixed-time ramp meter operates much like a pretimed traffic signal at an intersection. Its basic function is to break up platoons into single-vehicle entries and to set an upper limit on the flow rates that enter the freeway (8). Metering rates are based on average traffic conditions at a given ramp at a given time of the day (10). These rates are usually based on peak period conditions. Since peak period conditions are the most extreme conditions of the day, metering during less extreme periods results in less than optimum freeway operation.

In many cases, a fixed-time ramp meter may provide significant benefits over no control at all. In fact, the benefit-to-cost ratio may be greater than the other types of operation, depending on the freeway and ramp conditions. Chapter 10 of *Guidelines for*

Selection of Ramp Control Systems (11) demonstrates a methodology for estimating the benefit-to-cost ratio of a system.

Traffic-Responsive Operation

Traffic-responsive ramp meters utilize real-time traffic information received from detectors. With this type of operation, metering rates are based on current freeway traffic conditions. They are computed and updated periodically based on the current demand and capacity within the vicinity of the ramp (12).

System or Integrated Control

System or integrated control integrates a central control unit and communications link which can handle several ramps simultaneously. Metering rates are computed and updated based on freeway conditions throughout a significant length of freeway (12). A significant feature of this type of control is that it permits the metering rate at any ramp to be influenced by conditions at other locations.

Both fixed-time and traffic-responsive ramp meters help protect the capacity of a freeway. They each prevent the turbulence which occurs when too many vehicles enter from an entrance ramp. System or integrated control, however, is perhaps most useful in maintaining the overall traffic flow of a freeway. For example, if a bottleneck is detected on a freeway, the central control unit can decrease metering rates of ramp meters upstream of the bottleneck and increase metering rates at ramp meters downstream of the bottleneck.

Benefits

There are many benefits associated with ramp metering. "As long as mainline demand plus ramp traffic flow does not exceed capacity, throughput is maximized, speeds remain more uniform and congestion related accidents are reduced" (8). Ramp metering is not a new type of control. In fact, the first metered ramp was installed in Chicago on the Eisenhower Expressway in 1963 (8). Since then, several cities have been benefiting from ramp metering for several years. Some have experienced increased speeds and reduced travel times. Others have found that by metering their ramps, the freeway can handle higher volumes. The benefits of ramp metering in selected cities are summarized below.

Portland, Oregon

Ramp meters were installed along a six-mile section of I-5, the major north/south link of Portland, in January 1981 (8). The system consisted of 16 fixed-time ramp meters north of downtown. Nine northbound ramps were metered during the PM peak, and seven southbound ramps were metered during the AM peak.

Before the meters were installed, platoons of vehicles merging onto the freeway often caused congested traffic to slow down even further. The average speed of the northbound PM peak hour was 16 MPH. Fourteen months after the meters were installed, this speed had increased to 41 MPH. Furthermore, the average travel time was reduced from 23 minutes to 9 minutes. In the southbound AM peak, conditions were not as severe. Therefore, the benefits were not as pronounced. Average speeds in this direction increased from 40 MPH to 43 MPH.

Minneapolis/St. Paul, Minnesota

The Twin Cities have several ramp metering systems that have been implemented over a 20-year period (8). In 1970, the first two fixed-time meters were installed on southbound I-35E, north of downtown St. Paul. They were upgraded to traffic-responsive operation in November 1971. Four additional meters were also included. A recent study showed that after 14 years of operation, average peak hour speeds remained 16% higher than before metering. In addition, the freeway was able to accommodate a 25% increase in demand over the same time period.

Seattle, Washington

A rather unique application of ramp metering was implemented in Seattle in 1986 on SR-520 (8). Meters were installed on the two eastbound on-ramps on SR-520 between I-5 and Lake Washington (see Figure 1). The Lake Washington Blvd. on-ramp is the last entry point onto SR-520 before the Evergreen Point Floating Bridge. Since there were no bottlenecks on the bridge itself, traffic flowed freely east of this on-ramp all the way across the bridge. As a result, an excessive number of motorists used residential streets to go directly to the Lake Washington Blvd. on-ramp, thereby bypassing any potential upstream bottlenecks. Ironically, the high volumes on this on-ramp were the major contributing factor to upstream congestion. Therefore, one of the main objectives of the metering system was to reduce the number of motorists diverting through residential neighborhoods to reach the Lake Washington Blvd. on-ramp.

It was hoped that by metering the two on-ramps, the delay incurred by motorists at the Lake Washington Blvd. on-ramp would encourage them to enter SR-520 by the Montlake Blvd. on-ramp. Four months after operation, an evaluation showed a 43% decrease in the volume on the Lake Washington Blvd. on-ramp and an 18% increase in the volume on the Montlake Blvd. on-ramp.

A second objective of this ramp metering system was to encourage carpooling and transit use. Therefore, an HOV bypass lane was also installed at the Montlake Blvd. on-ramp. After four months of operation, a 44% increase in HOVs using the Montlake Blvd. on-ramp was observed.

A third objective of this ramp metering system was to improve traffic flow on SR-520. The same four month evaluation showed a 6.5% increase in mainline peak period volume.

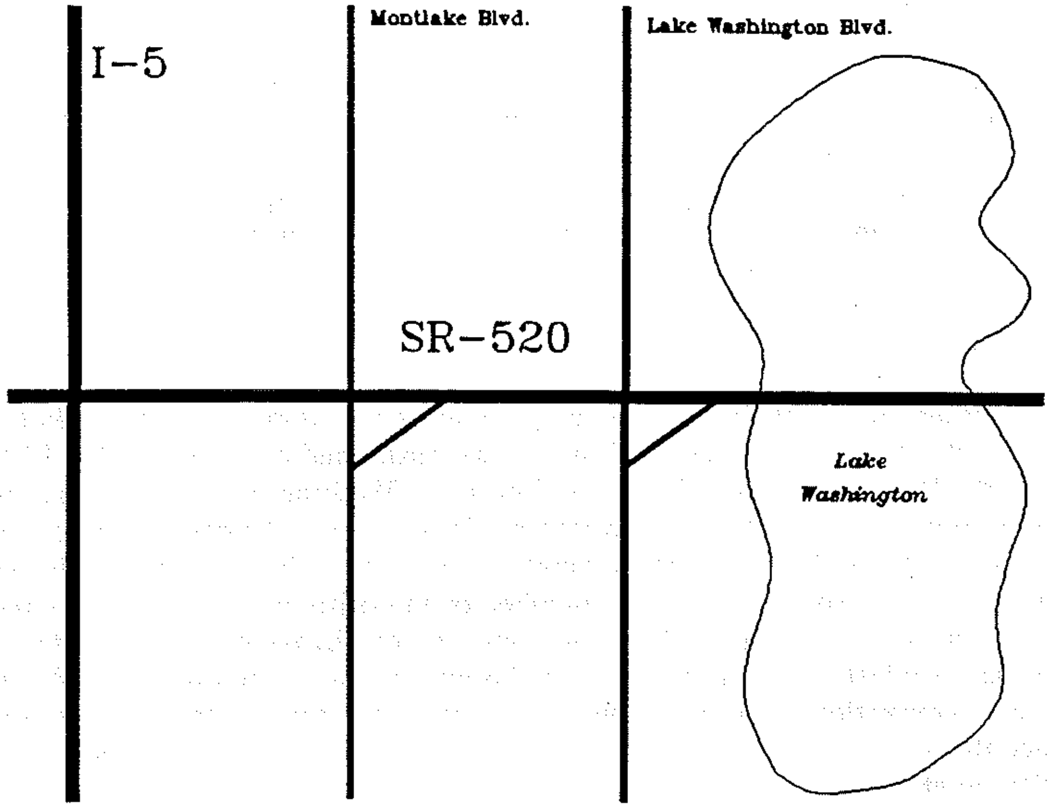


Figure 1. Map of SR-520 in Seattle, Washington.

Denver, Colorado

In March of 1981, a pilot project was initiated on a section of northbound I-25 to demonstrate the effectiveness of ramp metering (8). Five local traffic-responsive ramp meters operated during the AM peak. Eighteen months after the meters were installed, an evaluation revealed significant benefits. The system, therefore, was expanded to more than 26 meters and updated to system/integrated control.

The ramp metering system was put to the test when a new freeway, C-470, was completed. This freeway provided direct access to I-25 from the southwest area and generated higher demand. Because the freeway system was metered, I-25 was able to handle the higher demand without breaking down. In fact, volumes during the AM peak (in 3 lanes) increased from 6200 vph in 1981 to 7350 vph in 1989. That is, the ramp metering enabled the freeway throughput to increase from 2067 vphpl to 2450 vphpl.

In the Spring of 1987, an interesting "mishap" revealed the direct impact ramp metering had on the smooth operation of a freeway. Due to daylight savings time, all of the individual ramp controllers were adjusted one hour ahead. However, the central computer clock was overlooked. Therefore, ramp metering began an hour late. As a result, traffic was the worst it had been in years. Although this "evaluation" of ramp metering was unplanned, it certainly made people aware of its importance.

San Diego, California

Ramp metering was initiated in San Diego in 1968 (8). The system now includes 81 metered ramps on 40 miles of freeway. Although no comprehensive evaluations have been made on the system, volumes of 2200 vphpl to 2400 vphpl are common on the metered freeways.

Los Angeles

A traffic-responsive ramp-metering experiment resulted in a 100% increase in average speed (25 MPH to 52 MPH). It also resulted in a 20% decrease in ramp delays and a 3% increase in freeway volumes.

Ramp Closure

The benefits described above have clearly shown that ramp metering can effectively improve freeway operations. However, ramp metering is not a panacea for all types of congestion. Even with the use of metered ramps, freeways frequently have traffic demands that exceed the capacity of bottleneck sections. This results in congestion upstream of the bottleneck.

Ramp closure, another form of ramp control, can be used as a supplement to ramp metering. Closing selected ramps during peak periods further reduces traffic input to the freeway. Studies have shown that when ramp closure is implemented, freeway operation is improved (13),(14). Furthermore, where good alternative routes are available, diverted motorists only experience minimum additional delay.

A system of ramp closure was studied on the Gulf freeway in Houston in November 1972 (14). The conditions prior to ramp closure, the ramp closure system, and the resulting benefits are briefly described below.

Situation on the Gulf Freeway

On the Gulf Freeway, congestion problems occurred because of two bottleneck sections (see Figure 2). The first bottleneck was located at the Lombardy overpass, where a 5 percent grade reduced the capacity of the three inbound lanes. The condition was worsened because upstream entrance ramps added to the freeway volumes and frequently caused the demand to exceed the capacity of the Lombardy overpass. This resulted in congestion between the Telephone and Griggs overpasses.

The second bottleneck occurred at the Cullen entrance ramp, which had no ramp control. Heavy volumes entering on this ramp caused congestion in this area. When mainline and ramp volumes approached peak values, shock waves were generated upstream of the ramp. Once the freeway broke down, the traffic flow usually did not improve until after the peak period.

The sum of the volumes of the three entrance ramps and two exit ramps upstream of Lombardy overpass exceeded the capacity of the overpass by 500 vehicles between 7:00 and 8:00 a.m. One solution to this problem was to divert the entrance ramp traffic to the Dumble entrance ramp. Since approximately 600 vehicles exited at the Dumble exit ramp, the freeway would be able to accommodate the vehicles entering at Dumble. Therefore, it was proposed that the entrance ramps at Telephone, Wayside, Griggs, and Cullen be closed for short periods of time (15-20 minutes) during the peak period. The times of closure would depend on traffic conditions. Television monitors and electronic surveillance data would serve as indicators of impending congestion.

Ramp Closure System

In order to inform the motorists of the ramp closures, brochures were distributed at all four ramps on two weekdays prior to the ramp closures. The front of the brochure is illustrated in Figure 3. The brochure not only explained the study to the motorists but identified alternative routes.

The actual ramp closure was conducted manually by placing cones and barricades across the ramp, as illustrated in Figure 4. The ramps were closed each weekday during the morning peak period for seven weeks.

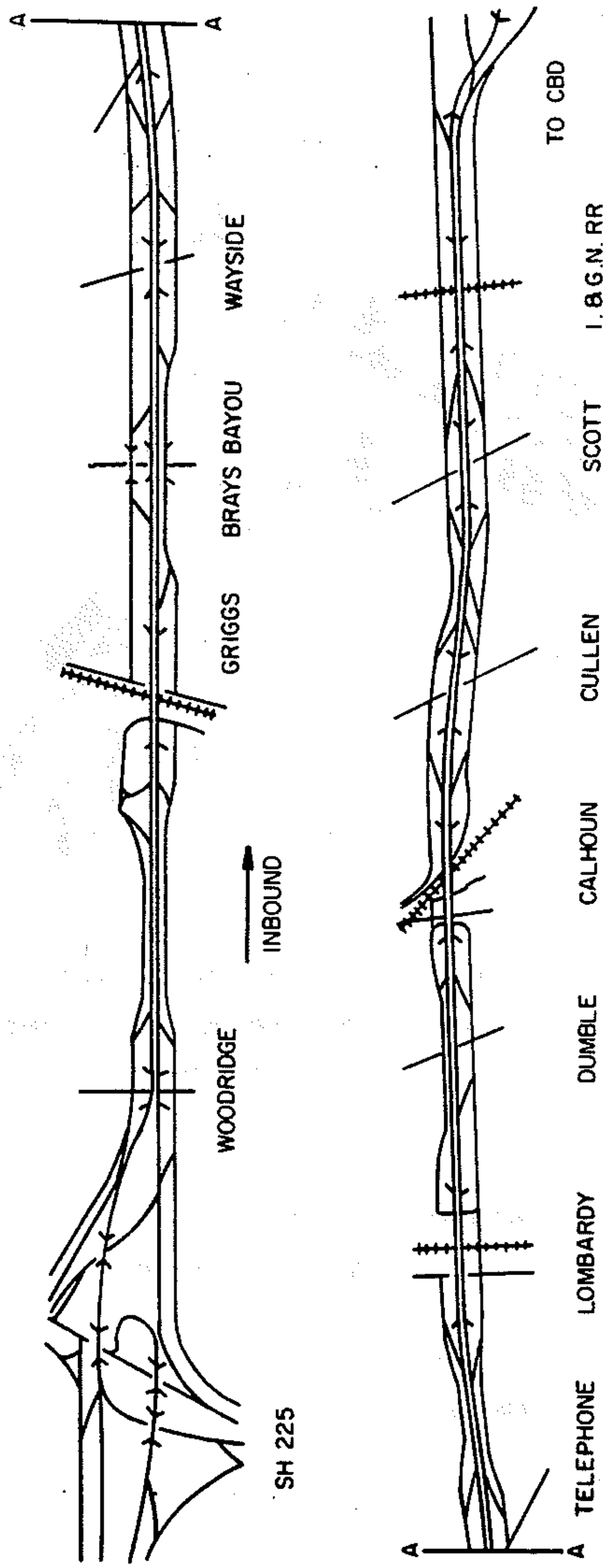
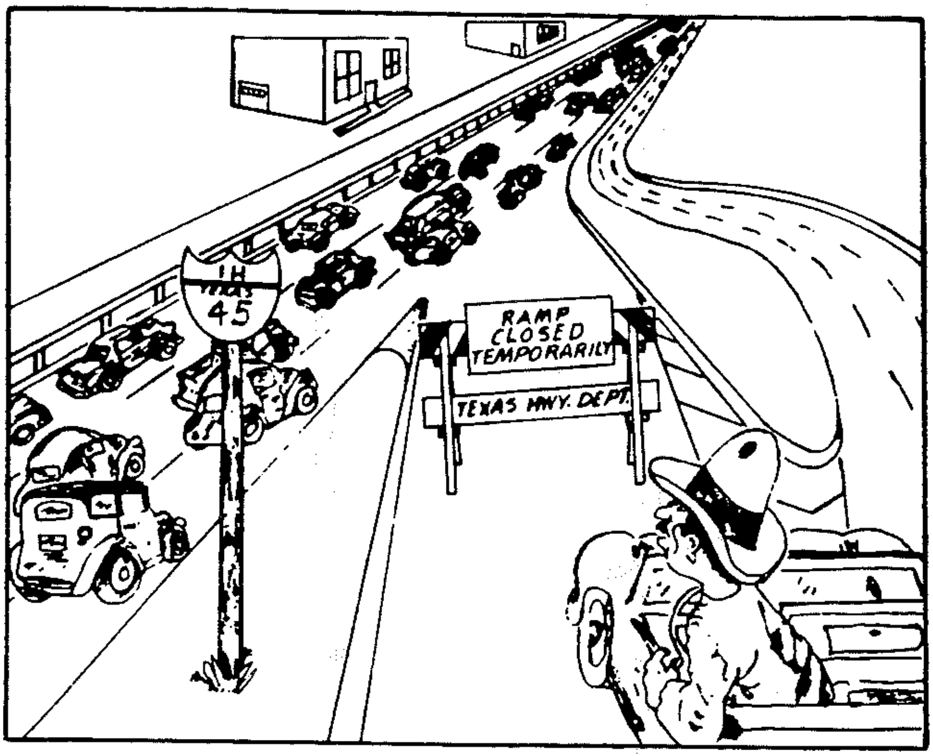


Figure 2. Map of the Gulf Freeway, Houston, Texas (14).



WHAT: GRIGGS RD., WAYSIDE DR., TELEPHONE RD., AND CULLEN DR. INBOUND ACCESS RAMPS TO BE CLOSED FOR APPROXIMATELY 15 TO 20 MINUTES

WHEN: BETWEEN THE HOURS OF 6:45 - 8:15 A.M. WEEKDAYS BEGINNING NOVEMBER 1, 1972

WHY : TO IMPROVE TRAFFIC FLOW IN THE GULF FREEWAY AREA

(SEE INSIDE FOR DETAILED INFORMATION)

Figure 3. Front of brochure informing motorists of ramp closure (14).

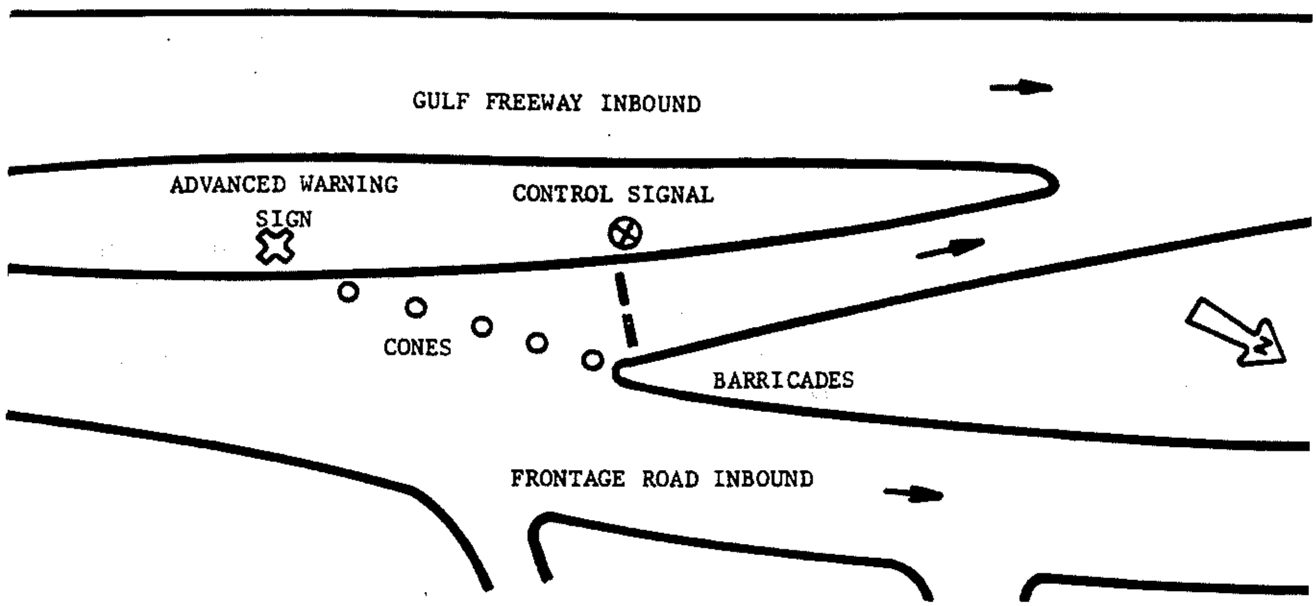


Figure 4. Method of closing entrance ramp (14).

Benefits

Evaluations of freeway operations were made before and during the closures. A comparison of the two evaluations revealed that several operational improvements resulted from the ramp closure. The following improvements in freeway operations were observed:

- Freeway volumes increased by 1.5 percent. In fact, volumes at the Griggs overpass increased by 5 percent.
- Speeds on the freeway increased by 20 percent.
- Fewer shock waves were observed during the ramp closure than prior to it. In fact, shock waves which normally occurred at the Lombardy overpass and at the Cullen entrance were not observed during the ramp closure.
- Peak period traffic cleared earlier than usual during the ramp closure study.

Ramp closure proved to be an effective form of ramp control in the Gulf Freeway study. It improved freeway operations during the peak period by reducing the upstream traffic demands. Although this study only included the closing of on-ramps, closing off-ramps may be equally effective in some cases. For example, if a high-volume on-ramp were followed by a high-volume off-ramp, it may be a good idea to close the off-ramp and encourage motorists to exit from an earlier off-ramp. If sufficient advance warning is given to the motorists, more capacity could be provided on the freeway for volumes entering from the on-ramp.

One concern with ramp closure, however, is that motorists may not be as accepting of it as they are of ramp metering. In this study, the distribution of brochures played a significant role in gaining public support. In fact, any complaints received were well-balanced by compliments.

Freeway-to-Freeway Metering

Another form of freeway control, which is not yet commonly used, is freeway-to-freeway metering. Ramps which serve as freeway-to-freeway connectors usually carry high volumes of traffic. In fact, these ramps can carry higher volumes than several cross-street ramps combined (15). If unmetered, these high volumes can cause congestion and accidents upstream. Due to the high volumes and speeds on freeway connectors, however, most cities hesitate to meter freeway-to-freeway ramps.

Several cities have experimented with freeway-to-freeway metering, some of which have been successful. San Antonio, for example, has metered one freeway-to-freeway interchange, and San Jose has at least three metered freeway-to-freeway interchanges (8). In addition, Minneapolis has successfully metered 12 freeway-to-freeway ramps (8).

The Minnesota Department of Transportation is probably the most experienced with freeway-to-freeway metering. They have been successfully metering freeway-to-freeway ramps for more than 20 years and currently meter 27 such ramps (15).

With freeway-to-freeway metering, care must be taken to analyze the metering rate and geometrics for each ramp. Furthermore, special attention must be given to providing sufficient storage length. If a freeway connector is suitable for metering, significant improvements in freeway operation can be achieved. The Minnesota Department of Transportation, for example, has discovered a net reduction in accidents and congestion with their freeway-to-freeway metering (15).

Alternative Work Schedules

Various positive controls have been discussed which help maintain traffic flow and prevent the breakdown of a freeway. The function of each of these controls is to regulate the rate at which demand is supplied to the freeway. Attention is now given to another type of control which also regulates demand, but in a different way.

Congestion is typically caused by "excessive concentrations of travel demand in space, time, and mode" (1). Traditionally, congestion has been relieved or eliminated by providing sufficient capacity in the spatial sense. However, it is usually only the peak periods in which traffic consistently breaks down. If sufficient capacity were provided during these two periods, the facility would be inefficiently used the rest of the day. Furthermore, the costs involved in providing peak-period capacity are very high.

Another approach to managing congestion focuses on the temporal concentration of travel demand. One such approach is alternative work schedules. The idea behind alternative work schedules is that the distribution of peak period traffic demand can be flattened. The cause of the familiar two peak periods of traffic demand is the existing work schedules. Therefore, any attempt to flatten these peaks should involve an alteration of work schedules.

Types

The three most common types of alternative work schedules are compressed workweeks, flexible work hours, and staggered work hours.

Compressed Workweek

This type of alternative work schedule compresses the normal schedule of 5 days per week into fewer than 10 days per 2-week period. Some examples include a four-day week, a four-and-a-half-day week, and a three-day week (1). Employees are assigned fixed working hours for the days they work. Of the three types of alternative work schedules, this is the most limited in its impact on traffic. This is because at least three days a week it does not affect the morning peak period. It only effects the demand during the evening peak period.

Flexible Work Hours

This type of alternative work schedule allows employees to choose their starting and stopping times. Although the employees are required to work a certain number of hours, they are often free to vary their schedule from one day to the next, vary their lunch hour, or bank hours from one day to the next. In some cases, they can even bank hours from one pay period to the next, depending on the program. Employees involved in flexible work hours are usually required to be present five days per week. The use of flexible work hours has some potential in flattening out the morning and afternoon peaks of travel demand. It is limited, however, in that the program is entirely voluntary. That is, employees may occasionally decide to travel during the peak periods, especially if traffic is flowing freely.

Staggered Work Hours

With this type of alternative work schedule, all employees work the same days each week and the same number of hours each day. However, their starting and stopping times are varied. For example, one group of employees may start at 7:00 a.m., another at 7:15 a.m., another at 7:30 a.m., etc. The variation of starting/stopping times is not limited to groups of employees within a company. The starting/stopping times could vary from one company to another within a central business district, from one division to another, or from one type of profession (i.e. financial district) to another.

Each employee's working hours are generally determined by the employer (with input from the employee). The employee is simply expected to work his or her assigned hours. This makes staggered work hours the most effective type of alternative work schedule in managing peak period demand. It is not a voluntary demand management technique, such as carpooling or riding transit. Therefore, it is not dependent on traffic conditions. In other words, regardless of how freely traffic may be flowing on the freeway, the employees still need to be at work at their respective starting times.

Example of Staggered Work Hours Program:

One of the most successful and thoroughly evaluated alternative work hours programs is one which was implemented in 1970 in New York City by the Port Authority of New York and New Jersey (1). Due to the overcrowding of several subway station platforms, staggered work hours were implemented with Port Authority employees at the World Trade Center Building in lower Manhattan. The impact of the staggered work hours program on worker arrival times is illustrated in Figure 5. It can be seen that the program virtually eliminated the dramatic peak of arrivals at 8:45 a.m. This flattening of the peak was a result of a 29 percent reduction (from 460 to 355) in the number of arrivals in the peak 5 minutes. Although this study was focused on subway riders, it demonstrates the effect of staggered work hours on the distribution of employee arrival and departure times.

Effect on Traffic

Flattening out the peaks of arrival and departure time distributions does not necessarily produce a corresponding change of equal magnitude in the peak traffic demand distributions. In fact, the impact of work rescheduling on the peak-period distribution of automobile traffic is less dramatic than the impact on employee arrival and departure distribution (1). There are two factors which play an important role in the extent to which traffic demand is affected by changes in work schedules. The first factor is the number of

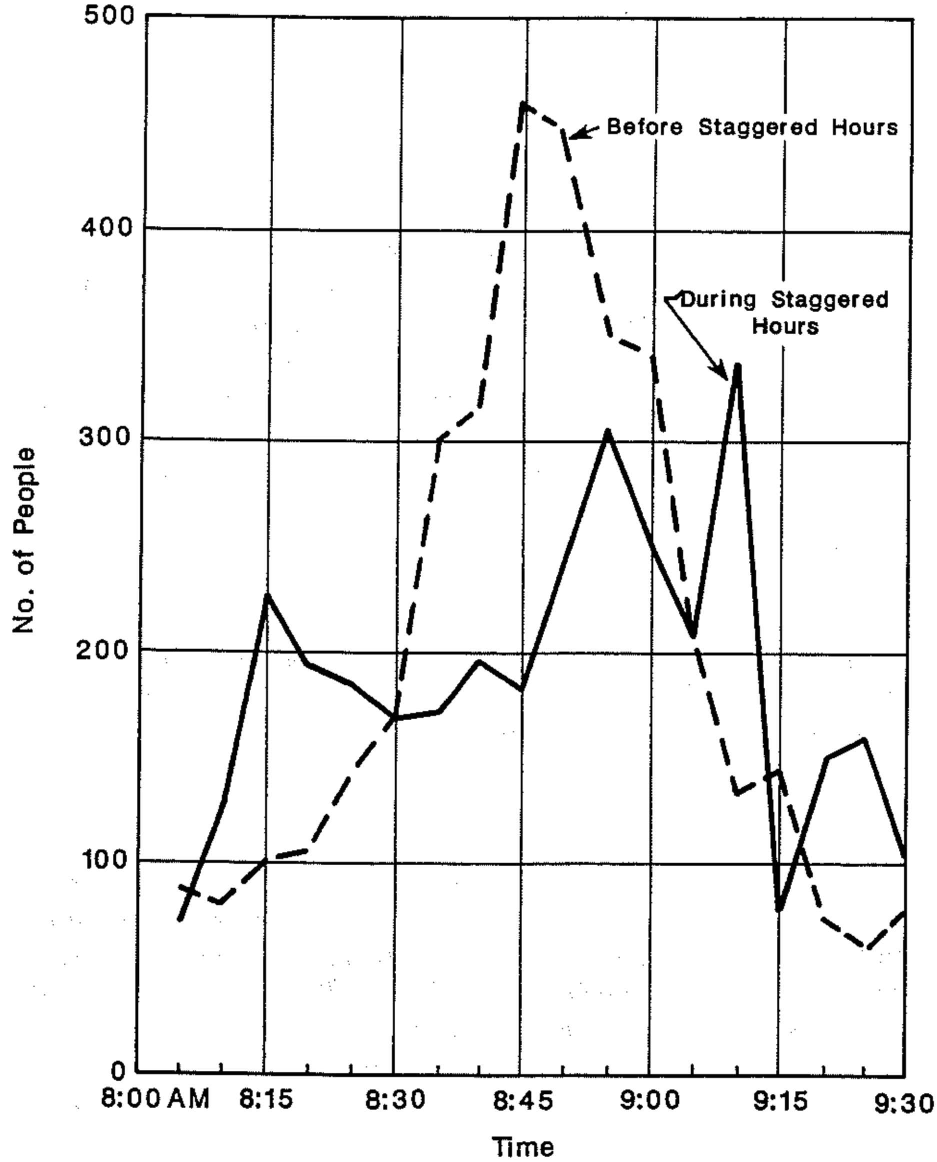


Figure 5. Impact of staggered work hours program on worker arrival time (1).

workers participating in alternative work schedule programs. Obviously, the more employee participants there are, the greater traffic volumes will be affected. The second factor is the proximity of a particular freeway to the employment areas involved in the program. The impact on traffic demand becomes more weakened as the distance from the employment area increases.

The effect of staggered work hours on traffic demand can also vary from one location to another. The following two studies came up with very different results.

Port Authority of New York and New Jersey Study

The Port Authority study of New York and New Jersey (16) analyzed the impact of the staggered work hours program in Manhattan on the peak-period distributions of traffic demand at three locations: the Midtown Tunnel, the Lincoln Tunnel, and the George Washington Bridge. The analysis revealed that no significant flattening of the peak-period traffic demands occurred as a result of the staggered hours program. One explanation for this is that the peak periods on these facilities were already very long before the program was implemented. In fact, the facilities were operating near capacity for almost the entire 3-hr morning and afternoon peak periods. Therefore, there was little capacity at the "shoulders" of the peak periods in which to shift any of the demand. This suggests that alternative work hours programs may be most effective in locations where the traffic demand exceeds capacity for relatively short periods of time. On the other hand, the work hours could be staggered a little more, such that the peak period began earlier. This could prevent the freeway from breaking down. One of the keys to breaking the congestion cycle is preventing breakdown from ever occurring.

Ottawa Study

A study in Ottawa (17) produced more successful results. In this study, half of the total CBD work force participated in staggered or flexible work hours programs. After the program was implemented, traffic counts were made at a screenline across which a high percentage of commuter traffic traveled to or from CBD jobs. Figure 6 illustrates the impact of the variable work hours on volumes at this screenline. During both the morning and afternoon peak periods, the traffic demand became more flattened. Unlike the Port Authority study, there was available capacity in the "shoulders" of the peak periods for shifted demand.

Organization

The Port Authority of New York and New Jersey study has demonstrated the positive effect staggered work hours can have on employee arrival and departure times. In addition, the Ottawa study has illustrated the significant impact staggered work hours can have on flattening the distribution of peak-period traffic demand. The key ingredient to the success of each of these programs was good organization in the design and implementation of the programs. To achieve an organized and, therefore, successful program, the following elements are necessary: government agency involvement, commitment from public officials and private-sector leaders, and a staged or incremental approach (1).

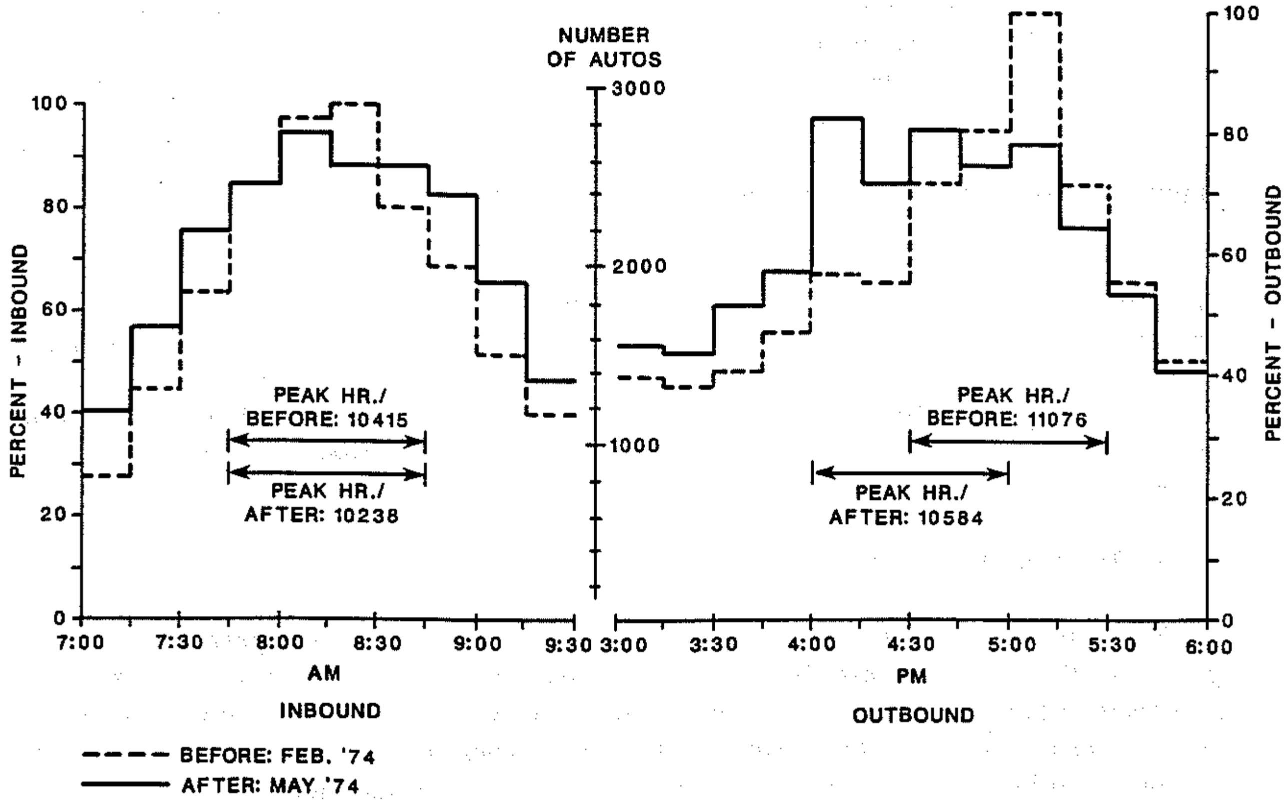


Figure 6. Impact of variable work hours on automobile volumes at the Ottawa central area screenline (1).

Government Agency Involvement

It is almost imperative that an agency take a leadership role in the planning and implementation of a staggered work hours program. The agency's responsibility would be to gain support from the various participating organizations and help in the coordination process. The agency could distribute an implementation support package consisting of "guidelines, model employee communication packages, explanations of alternative timekeeping systems, and internal evaluation feedback mechanisms" (1).

This agency could be a metropolitan planning organization, a state or city transportation agency, a regional transit authority, or some other organization depending on the urban area. It may also be a group made up of representatives from several agencies. Although many employers develop alternative work schedules on their own, the involvement of a lead agency can "expand, facilitate, and increase the effectiveness of these programs"(1).

Commitment From Public Officials and Private-sector Leaders

It would be difficult to achieve a successful program without the support of public officials and private-sector leaders. Public officials can play an active role in rallying community support in alternative work hours programs. For example, they could promote such programs through the media or through other public information activities, or make the promotion part of their own campaigns. Similarly, private-sector leaders can spur enthusiasm amongst their own employees. For example, the benefits of such a program could be discussed in employee meetings or explained in memos.

Staged or Incremental Approach

Some urban areas may be very reluctant to implement a staggered work hours program. In these cases, it may be necessary to begin with small pilot projects with a few employers who have a particular interest in alternative work schedules. Depending on the success of these programs, they can be used as a basis for the planning of additional programs. Caution must be taken, however, to avoid picking too small of a pilot project. Some benefits must be shown in order to gain support for additional programs.

The success of any work rescheduling program is more likely if a staged incremental approach is taken. In fact, it should be well-understood by participants that it may take several years before a work rescheduling program can be implemented areawide.

PUBLIC EDUCATION CAMPAIGN

As previously discussed, motorists involved in some form of ridesharing have little incentive to continue doing so if no congestion exists on the freeway. However, before attempting to change the motorists' attitudes, it is important to remember that "attitudes are the product of perceptions" (18). Therefore, what must be changed is not necessarily the motorists' attitudes but how they perceive congestion. Thus, one of the best ways to break the congestion cycle is to launch a massive public education campaign in which motorists are taught that a freely flowing freeway could well be on the brink of total breakdown. They must also understand that without positive controls the freeway would be congested.

Design of Campaign

A public education campaign such as this should be designed to target four groups: the driver, the employer, the public official, and employees within the transportation organization.

The Driver

The driver is perhaps the most important of the four groups. It is the driver who makes decisions daily about whether to carpool or ride public transit. It is also the driver who violates ramp meters when he does not see their value or purpose. Therefore, the driver needs to be taught that it is because of the carpooling, the public transit, and the ramp controls that there is no congestion.

The Employer

The employer can play one of the most significant roles in traffic demand management techniques. He has the opportunity to arouse enthusiasm for ridesharing amongst his employees. In addition, he can develop staggered work hours programs. If the employer does not see the importance of positive controls, it is likely his employees--the motorists--will not either.

The Public Official

The politician is also an important target of a public education campaign because he can have a significant effect on the attitudes of the public. For example, if a politician does not see the benefits of ramp controls or staggered work hours, he will attack their importance in his own campaign for office. Since the success of many transportation programs depends on the support of the politicians, it is vital that they understand the need for such programs.

The Employees Within a Transportation Organization

Disagreements within a transportation organization often hinder the success of a program. Some employees may believe that the traditional methods of managing traffic are superior to new ideas. On the other hand, other employees may feel that the implementation of new ideas is worthwhile. For example, freeway-to-freeway metering could be a potentially controversial issue within a transportation organization. Since freeways have traditionally been operated without traffic signals, some employees may feel that the volumes and speeds on freeway would make metering an unsafe form of control. Therefore, a campaign describing the importance and safety of freeway-to-freeway metering would need to be aimed at these employees before it could ever be successful outside of the office.

Contents of Campaign

The information presented to the public should be simple and straightforward. The public needs to be informed that although the freeway is operating at free flow, it may be running at around 95% of its capacity. They need to know that at this point any minor disruptions can throw the freeway into congestion. The necessity of positive controls should be stressed.

It would be wise to hire advertising and public relations specialists to come up with the most effective way of presenting the information. A catchy phrase is often the key element of a campaign's success.

Implementation of Campaign

There are numerous methods of distributing information to the public. At the National Conference on Corridor Traffic Management for Major Highway Reconstruction, a group of experts generated a list of means for making information available to the public about reconstruction projects (19). These means are also applicable to a public education campaign. The list includes:

- door-to-door handouts;
- direct mass mailings, or indirect mailings using materials designed for enclosure with utility bills, sports/cultural event season ticket holders, book club mailings, and so on;
- handouts at parking garages, intersections and ramps, parking lots, and on buses and on trains;
- interview with news media;
- informational materials distributed through employers, labor and political organizations, chambers of commerce, various professional and business associations;
- announcements at public events;

- paid advertising;

- speakers bureaus.

Without a massive public education effort, participation in voluntary demand management strategies will continue to be dependent on the presence of congestion. Unless the public understands how unstable freeflow conditions can be, it will be extremely difficult to gain areawide support of ramp controls and staggered work hours programs.

CONCLUSIONS

Positive controls are an essential part of breaking the congestion cycle. By regulating freeway input, they can prevent congestion from returning after an improvement has been made in traffic flow thus breaking the congestion cycle. In this paper, four types of positive controls have been discussed. Significant benefits were experienced with each.

Several cities have experienced tremendous benefits from the implementation of ramp metering systems. Ramp metering can increase speeds, decrease travel times, and increase the throughput of a freeway. Furthermore, public acceptance of ramp metering has been very good in most cases.

Ramp closure is another type of ramp control. One study showed that ramp closure can eliminate a bottleneck on a freeway. This is accomplished by shifting the demand upstream of a bottleneck to a downstream ramp. Furthermore, if motorists are properly informed and provided with clear alternative routes, public acceptance will not be a problem.

Freeway-to-freeway metering is a type of ramp control less frequently used. It can be a useful tool in maintaining the flow at freeway interchanges. By metering a freeway connector, the typically high volumes can be regulated.

While ramp controls manage spatial demand, staggered work hours programs can be an effective means of controlling temporal demand. Staggered work hours programs flatten the distribution of peak period demand on a freeway. The magnitude of their effect on traffic, however, depends on the number of participants in the program and the location of participating employment centers relative to the freeway. The impact of these programs is greatest if the peak periods are relatively short.

One of the most important tasks in breaking the congestion cycle is to convince the public that a freeway which appears to be uncongested may actually be on the verge of breaking down. This can be done through a massive public information campaign. Professional advertising and public relations personnel may be instrumental in the success of the campaign.

RECOMMENDATIONS

In order to break the congestion cycle, more emphasis needs to be placed on positive controls. Ramp metering systems should be considered at locations where the turbulence of entering traffic causes shockwaves and leads to congestion, and in locations where demand regularly exceeds capacity. Where bottlenecks are present, ramp closure should be used as a supplement to ramp metering. In addition, transportation engineers need to become more open to freeway-to-freeway metering. The high merging volumes at freeway connecters can be successfully regulated.

The main cause of peak period congestion is commuter travel demand. Staggered work hours have proven effective in spreading this demand throughout the peak periods. Transportation agencies should play a lead role in the development and implementation of areawide staggered work hours programs.

Finally, massive public education campaigns need to be launched in order to gain the public support of positive controls. Motorists must understand that an uncongested freeway can easily become congested unless controls are enforced.

By no means should positive controls be used in place of voluntary demand management techniques. Techniques such as HOV facilities, ridesharing programs, public transit, and alternative work schedule programs (other than staggered work hours) are also needed. In fact, it is recommended that all these techniques, voluntary and positive, be combined into an overall comprehensive demand management program in an effort to break the congestion cycle.

ACKNOWLEDGEMENTS

The author would like to express her sincere gratitude to David Roper of Roper and Associates, Inc., for his direction, technical guidance, and encouragement throughout this project. Special thanks also goes out to Joseph McDermott, Don Capelle, Randy Keir, and Ed Rowe for their time, professional input, and challenging discussions. The author wishes to express appreciation to Drs. Conrad Dudek and Carroll Messer for organizing this class.

In addition, the author would like to thank the following transportation professionals who were interviewed during the course of this research:

Glen Carlson -- Manager, MN Dept. of Transportation
Louis Lipp -- District Traffic Engineer, CO Dept. of Highways
Ron Sonntag -- District Chief Freeway Engineer, WI Dept. of Transportation

REFERENCES

1. Transportation Research Board. "Alternative Work Schedules: Impacts on Transportation." *NCHRP Synthesis of Highway Practice No. 73*. Washington, DC. November 1980.

2. *Transportation News*. Vol. 17, No. 5. Texas Department of Transportation, Austin. January 1992.

3. R. Sonntag. Telephone interview conducted on June 19, 1992.

4. L. Lipp. Telephone interview conducted on June 19, 1992.

5. G. Carlson. Telephone interview conducted on June 19, 1992.

6. A.D. May. *Traffic Flow Fundamentals*. Prentice-Hall, Englewood Cliffs, NJ. 1990.

7. J.M. McDermott, S.J. Kolenko, and R.J. Wojcik. *Chicago Area Expressway Surveillance and Control: Final Report*. Illinois Department of Transportation, Springfield, IL. March 1979.

8. J. Robinson, and M. Doctor. "Ramp Metering Status in North America." Report No. DOT-T-90-01. Federal Highway Administration, Washington, DC. September 1989.

9. T.F. Humphrey, and C.K. Orski. *Toolbox for Alleviating Traffic Congestion*. Publication No. IR-054A. Institute of Transportation Engineers, Washington, DC. 1989.

10. C.W. Blumentritt, C. Pinnell, W.R. McCasland, D.W. Ross, and J. Glazer. "Guidelines for Selection of Ramp Control Systems." *NCHRP Report 232*, National Cooperative Highway Research Board, Transportation Research Board, National Research Council, Washington, D.C. May 1981.

11. R. Wilshire, R. Black, R. Grochoske, and J. Higinbotham. "Traffic Control Systems Handbook." Report FHWA-IP-85-11. Federal Highway Administration, Washington, DC. April 1985. - Cited in C.L. Dudek and G.L. Ullman. "Freeway Corridor Management." *NCHRP Synthesis of Highway Practice No. 177*. NCHRP Synthesis of Highway Practice 177, National Cooperative Highway Research Board, Transportation Research Board, National Research Council, Washington, D.C. March 1992.

12. C.L. Dudek, and G.L. Ullman. "Freeway Corridor Management." *NCHRP Synthesis of Highway Practice No. 177*. NCHRP Synthesis of Highway Practice 177, National Cooperative Highway Research Board, Transportation Research Board, National Research Council, Washington, D.C. March 1992.

13. R.C. Loutzenheiser. "The Effects of Entrance Ramp Closure on Freeway Operation During Morning Peak Periods." Research Report 139-9. Texas Transportation Institute, College Station, TX. August 1971.

14. W.R. McCasland, and J.H. Ibanez. "Study of Traffic Responsive Ramp Closure Control." Research Report 165-11. Texas Transportation Institute, College Station, TX. August 1972.

15. Traffic Management Center Staff, *Overview of the MNDot Ramp Metering Program*. Report No. TMC 07043-292. Minneapolis, MN. May 1992.

16. Port Authority of New York and New Jersey. *Staggered Work Hours Study. Design and Implementation of Staggered Work Hours in Manhattan.* Volume II--*Technical Report: Final Report on Phase I.* 1977. - Cited in Transportation Research Board. "Alternative Work Schedules: Impacts on Transportation." *NCHRP Synthesis of Highway Practice No. 73.* Washington, DC. November 1980.

17. R. Safavian, and K.G. McLean. "Variable Work Hours: Who Benefits." Regional Municipality of Ottawa, Ontario. 1974. - Cited in Transportation Research Board. "Alternative Work Schedules: Impacts on Transportation." *NCHRP Synthesis of Highway Practice No. 73.* Washington, DC. November 1980.

18. G.E. Gray, and L.A. Hoel. *Public Transportation.* Prentice-Hall, Englewood Cliffs, NJ. 1992.

19. Roundtable participants. "Transportation Management for Major Highway Reconstruction." Proceedings of the National Conference on Corridor Traffic Management for Major Highway Reconstruction. Chicago, IL. September 28-October 1, 1986.

Ingrid B. Anderson received her B.S. in May 1990 from North Park College in Physics and is currently pursuing her M.S. from Texas A&M University in Civil Engineering. She has been employed by the Texas Transportation Institute as a Graduate Research Assistant since July 1990. She has been involved with the Projects Committee in the Institute of Transportation Engineers. Her areas of interest include: geometric design and highway safety.