

THE EFFECTS OF ENTRANCE RAMP CLOSURE
ON FREEWAY OPERATION DURING
MORNING PEAK PERIODS

by

Roy C. Loutzenheiser
Engineering Research Associate

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ABSTRACT

Ramp metering, which is a regulatory but voluntary form of control, is effective for improving freeway operations. However, traffic input demand frequently exceeds the capacity of some freeway bottlenecks resulting in upstream congestion. This study discusses the use of positive ramp closure during peak periods to further reduce traffic input to the freeway from a selected ramp. The conclusions are that freeway operation is improved, while diverted motorists experience only minimum added delay. Further research is needed to establish when and what length of time a ramp should be closed.

DISCLAIMER

The opinions, findings, and conclusions expressed or implied in this report are those of the research agency and not necessarily those of the Texas Highway Department or the Federal Highway Administration.

SUMMARY

One of the objectives of Project 139 entitled "Freeway Control and Information Systems" is to develop a freeway control system that will control demand on the freeway lanes. Control has usually been in the form of ramp metering, which is a regulatory but voluntary form of control. This report pertains to a study of positive ramp closure intended to reduce traffic input to a bottleneck area during peak periods.

The traffic demand on the inbound Gulf Freeway often exceeds the capacity of the Lombardy overpass producing shock waves that move upstream through the system. To reduce the demand at the Lombardy overpass, the Telephone entrance ramp was closed by positive means on weekdays from 7:00 to 8:00 a.m. for two weeks. The following findings are drawn from the evaluation presented in this report:

1. Freeway speeds upstream of the Telephone entrance ramp increased, while freeway speeds upstream of the Griggs, Wayside, and Dumble entrance ramps decreased. The average freeway speed for the system did not change.
2. Shock waves normally propagated at the Lombardy overpass were not observed during the closure study.
3. Freeway volume over the Telephone overpass was slightly decreased during the closure study.
4. Motorists diverted from the Telephone entrance ramp had an added delay of two to five minutes, which was probably not

noticeable to most motorists. The Freeway Surveillance Office did not receive any calls of citizen complaints about the closure, even though the telephone number of the office was included in a handout.

Implementation

The results of this study suggest the need for further research.

The following recommendations are made:

1. A series of similar studies involving all of the entrance ramps to the Gulf Freeway Surveillance and Control area should be conducted. These studies should further define the conditions and length of time for ramp closure.
2. A study should be made of the possible means for automatically initiating closure and advising motorists of the closure.
3. A decision matrix for each ramp should be developed with the operational and managerial options outlined for the operating agency.

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INTRODUCTION

To improve the peak period operation of an urban freeway when demand frequently exceeds capacity, freeway entrance ramps are regulated by real-time control. This control is usually in the form of metering by ramp signals, which is a regulatory but voluntary form of control. Many freeways, however, still have bottleneck locations with limiting capacity where congestion often occurs. The basic problem is that traffic demand exceeds the bottleneck capacity even when real-time control is activated.

Congestion is reduced at these bottlenecks by eliminating geometric inadequacies or by decreasing upstream traffic demand. Since the modification of a bottleneck area is costly and the construction causes some congestion, this method is usually not desirable. Further reduction of upstream traffic demand is probably less expensive and easier to effect. Methods to effect such a reduction are on-freeway control and entrance ramp control, either of which may be positive or voluntary.

A Problem on the Gulf Freeway

The traffic flow on the inbound Gulf Freeway becomes congested upstream of the Lombardy overpass during the morning peak period. The restriction in flow is caused by the five per cent grade at the overpass and the proximity of three entrance ramps and two exit ramps upstream of the overpass. When the traffic demand exceeds the capacity at the Lombardy overpass, a shock wave moves upstream through the system. This shock wave causes the freeway to become congested between the Telephone

and Griggs overpasses and often reflects back to the SH 225 Interchange (see Figure 1). The operation upstream of the Telephone overpass usually does not regain a desirable level of service until after the peak period, because the demand at the three entrance ramps in the area is too high, even with ramp metering control. The merging operations of the ramps cause reduced flow and speeds in the outside lane. Downstream of the Telephone overpass, the reduced flow permits the operation at the Lombardy overpass to return to a desired level of service.

The three inbound lanes have a theoretical capacity of 6,000 VPH. The five percent grade at the Lombardy overpass, however, reduced the capacity to less than 5,400 VPH, based on calculations from the "Highway Capacity Manual" (1). The three entrance ramps add approximately 850 vehicles between 7:00 and 8:00 a.m., while less than 350 vehicles leave the freeway at the two exit ramps. When these 500 vehicles are added to the upstream freeway volume of 5,100 vehicles, the demand exceeds the capacity of the Lombardy overpass.

The Objective of This Study

The input-output movements between Griggs and Lombardy overpasses appear to cause the reduction in freeway flow at the Telephone overpass. To improve the total freeway operation, it was proposed that the Telephone entrance ramp be closed from 7:00 to 8:00 a.m. to reduce the input demand to the subsystem. Vehicles entering the freeway at this ramp have an alternate route along the frontage road to the next entrance ramp downstream of the bottleneck. The ramp would be closed with cones and barricades to insure a positive form of closure.

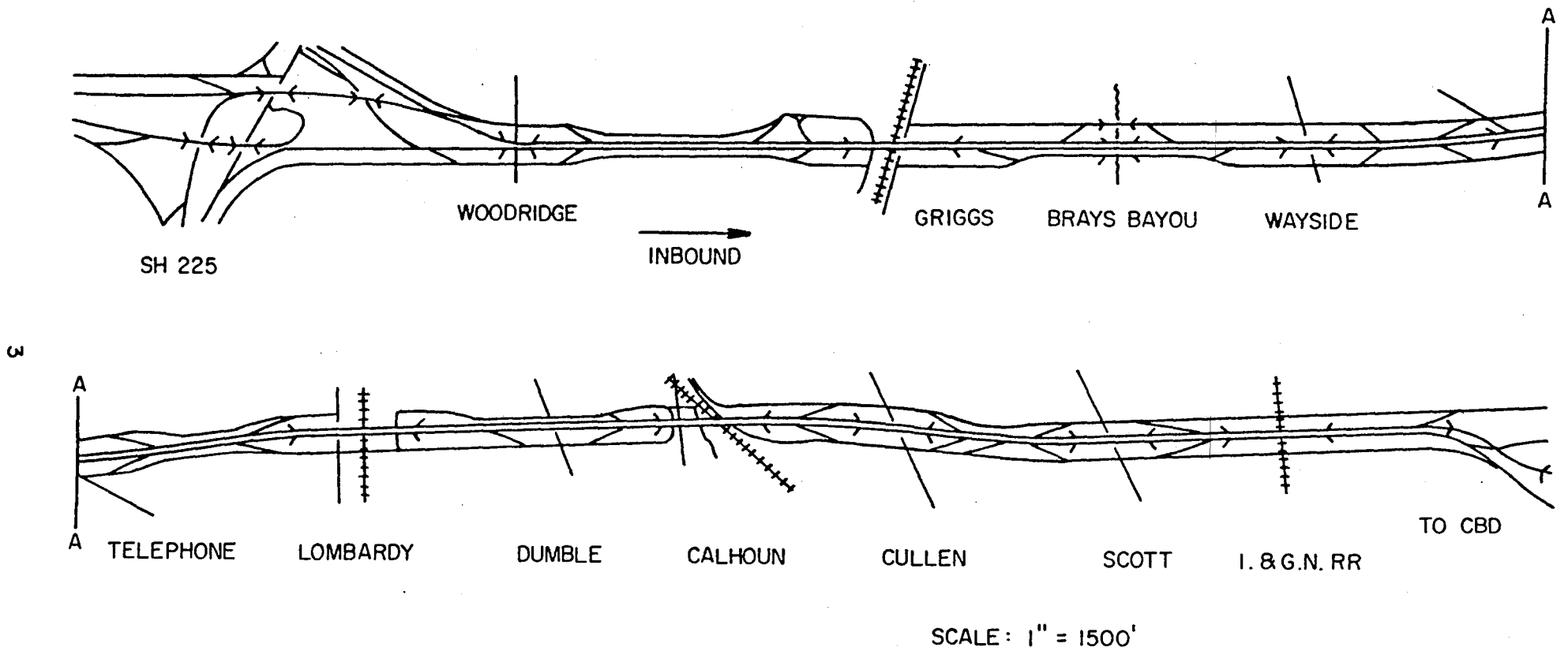


Figure 1. Map of the Gulf Freeway , Houston , Texas.

STUDY PROCEDURES AND PRELIMINARY ANALYSIS

Data were collected before the actual closure to identify normal freeway and ramp operation parameters and to provide information on alternate routes for motorists normally using the Telephone entrance ramp. A brochure was passed out to the motorists at the Telephone entrance ramp on two weekdays before the actual closure to explain the study and to suggest alternate routes. A copy of this brochure is shown in the Appendix. The ramp was closed on weekdays for two weeks (from April 26 through May 7) from 7:00 to 8:00 a.m. and appropriate data were collected.

Subsystem Analysis Prior to Closure

Within one mile upstream of the Lombardy overpass, there are three entrance ramps and two exit ramps. The three entrance ramps have a total volume of about 850 vehicles between 7:00 and 8:00 a.m., while the exit ramps have less than 350 vehicles (see Table 1 for data). About 600 vehicles between 7:00 and 8:00 a.m. leave the freeway at the Dumble exit ramp which results in available freeway capacity downstream of the Lombardy overpass. Closure of either the Griggs or the Wayside entrance ramps would cause diversion of vehicles to the next downstream entrance ramp, the Telephone ramp, and therefore would not necessarily reduce the demand at the Lombardy overpass. Closure of the Telephone entrance ramp, however, would cause significant diversion to the Dumble entrance ramp where freeway capacity is available.

TABLE 1

SUMMARY OF ENTRANCE RAMP DATA

PARAMETER	Griggs			Wayside			Telephone			Dumble			TOTAL		
	B	D	A	B	D	A	B	D	A	B	D	A	B	D	A
Between 7:00 & 8:00 a.m.															
Average Queue	12	11	12	10	10	12	8	--	9	10	14	8			
Maximum Queue	18	15	16	15	16	17	13	--	14	13	20	12			
Average Delay (Min.)	2½	2½	N	2	2	N	2	--	N	1½	2½	N	8	7	N
Maximum Delay (Min.)	3	3	N	2½	3	N	3	--	N	2½	3½	N	11	9½	N
Percent Violators	2.8	4.6	3.2	5.9	5.8	9.9	6.3	--	10.7	1.9	9.0	4.2	16.9	19.4	28.0
Volume															
7:00 - 8:00 a.m.	282	301	268	287	296	285	288	0	248	355	496	385	1212	1093	1186
6:30 - 8:30 a.m.	617	630	607	534	540	514	512	213	453	599	748	640	2262	2131	2214

NOTE: B = Before Two Week Closure
D = During Two Week Closure
A = After Two Week Closure
N = Not Available

To justify the closure of the Telephone entrance ramp, the expected delay to the 300 diverted motorists was studied. Four possible diversion alternatives exist: (a) use the Telephone ramp before 7:00 or after 8:00 a.m.; (b) use the Griggs or Wayside entrance ramp; (c) use Telephone Road northbound; or (d) use Dumble entrance ramp (see Figure 2). Delay for the first two alternatives would be minor, and in fact would probably be less than normal delay. However, there would be some inconvenience to the motorists who change their trip schedule. The motorists using Telephone Road would experience additional travel time to their destination; however, it is assumed that motorists would not choose this route unless their destination was near Telephone Road. Previous research (2) indicated that travel to a downtown distribution point by way of Telephone Road requires between two and five minutes more than traveling on the Gulf Freeway during normal peak flow conditions.

Delay caused by using the Dumble ramp would be due to the railroad crossing or the added queue at the Dumble ramp. The traffic signal next to the railroad crossing may cause about 30 seconds delay, unless a train blocks the frontage road. Train movements between 7:00 and 8:00 a.m. were observed for thirty weekdays to obtain the following:

- (a) nineteen trains were observed on sixteen different days,
- (b) the minimum blockage was one minute and a maximum blockage was twelve minutes, and
- (c) the average blockage was 4.4 minutes per train and 2.5 minutes per day.

Therefore, delay due to the trains is infrequent and amounts to less than five minutes per train.

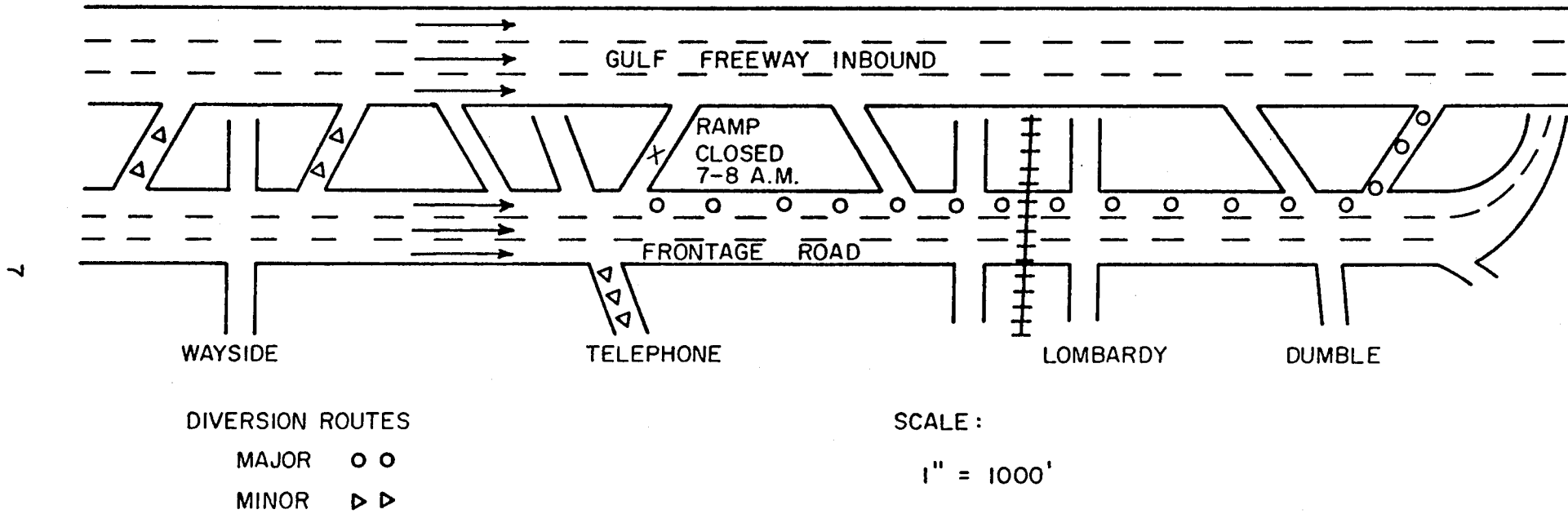


Figure 2. Diversion routes during ramp closure.

Approximately 360 vehicles use the Dumble entrance ramp between 7:00 and 8:00 a.m., and the average queue length is less than ten vehicles. This means that a motorist must wait about one minute for a normal metering rate of about ten vehicles per minute to enter the freeway. It was assumed that 200 of the 300 vehicles from the Telephone entrance ramp will divert to the Dumble entrance ramp. Distributing these vehicles over the 7:00 to 8:00 a.m. period would result in an increase in queue length of three to four vehicles and ramp delay of approximately one-half minute.

Excluding the railroad crossing and ramp delay, vehicle travel time is increased by about one-half minute when comparing the frontage road route (about 30 MPH speed) and the freeway route (less than 40 MPH speed) for the one-mile distance. Therefore, a motorist diverted to the Dumble entrance ramp would have a total added delay of about two minutes normally and up to seven minutes when a train blocks the frontage road.

If each of the 300 vehicles normally using the Telephone entrance ramp is diverted and has an assumed delay of five minutes, a total delay of 1,500 vehicle-minutes would result. However, if the ramp closure resulted in increasing the average 7:00 to 8:00 a.m. freeway speed between Griggs entrance ramp and Dumble entrance ramp (a distance of $1\frac{1}{2}$ miles) from 29.8 (the existing speed) to 33 MPH, the freeway delay would decrease 1,500 vehicle-minutes offsetting the increased ramp traffic delay. Similarly, if the average freeway speed between SH 225 and the Dumble overpass was increased from 30.5 to about 32 MPH, a total freeway savings of 1,500 vehicle-minutes would occur.

Distribution of Information to Motorists

To inform motorists of the purpose of the ramp closure and to suggest alternate routes, a brochure was distributed to each motorist using the Telephone entrance ramp between 6:45 and 8:15 a.m. on the two weekdays before the closure (April 22 and 23). A city policeman was present during the distribution of the brochures. A total of 400 and 318 brochures were issued on the first and second day, respectively. On the second day, motorists who indicated that they had already received a brochure were not given a second.

Ramp Closure

The Telephone entrance ramp was closed at 7:00 a.m. by placing cones in front of two barricades as shown in Figure 3. Placement of the cones on the ramp took less than two minutes and preceded the barricade installation. At 8:00 a.m., the barricades were removed and then the cones, so traffic was using the ramp within a few minutes. The control signal, which normally operates at the ramp, was turned off when the ramp was closed and turned on when it was opened. This was necessary since an advanced sign saying "ramp metered when flashing" operates concurrently with the ramp signal. The ramp was closed each weekday morning for two weeks from April 26 to May 7, 1971.

During the study, no complaints were received at the Surveillance Office. However, the first day of the study was the first weekday of Daylight Savings Time. This probably had a significant effect on the flow between 7:00 and 8:00 a.m. since some motorists, such as construction employees, probably went to work earlier because of the extra daylight

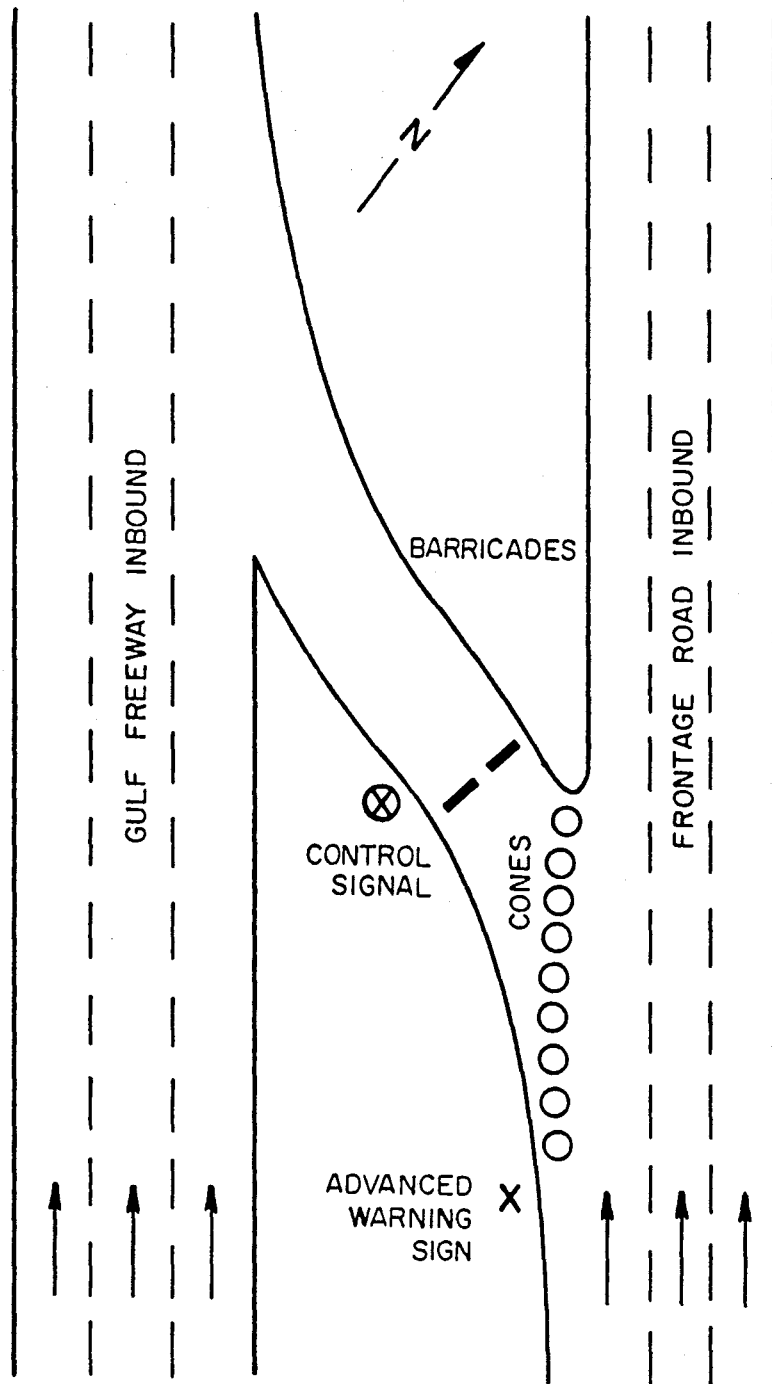


Figure 3. Method of closing Telephone entrance ramp.

hour in the morning. The "after" study was affected by the University of Houston having its final examinations during the week of May 10 through May 14. Fewer students and staff members traveled to the University before 8:30 a.m. These scheduling problems should be avoided in studies of this type if possible.

ANALYSIS OF DATA

A summary of freeway data is shown in Table 2. These data are for days of normal operation that were not affected by lane blocking incidents. The following days were analyzed:

Before Closure - April 13, 16, 19, 20

During Closure - April 27, 30, and May 4, 7

After Closure - May 11, 12

The data analysis is based on the above days unless otherwise indicated. Analysis of "after" data was limited due to the effects of the University of Houston examination schedule. Comparison of "before" and "after" volumes indicate a decrease in flow.

Freeway Operation

The freeway had a two percent decrease in volume during the closure study. Two factors account for this decrease: the beginning of Daylight Savings Time and the study length of only two weeks. The motorists were in the process of changing their driving habits due to the beginning of Daylight Savings Time and the ramp closure. A comparison of "before" and "after" volumes also indicated a decrease in flow. A longer study would have permitted the motorist to adjust to the time change.

The speed upstream of the Telephone entrance increased about five percent. This was apparently due to the elimination of the merge between the ramp traffic and the outside freeway lane traffic. A comparison of five minute counts on the outside lane upstream of the Telephone entrance

TABLE 2
SUMMARY OF FREEWAY AND
FRONTAGE ROAD DATA

Location	Volume in Vehicles per Three Lanes			Average Speed (MPH) ¹		
	Before	During ²	After	Before	During	After
Griggs Overpass						
7:00 - 8:00 AM	5510	5422	5584	32.2	27.5	26.8
6:30 - 8:30 AM	10643	10501	10491	40.2	34.1	30.5
Telephone Overpass						
7:00 - 8:00 AM	5656	5536	5620	29.8	31.3	30.3
6:30 - 8:30 AM	10779	10525	10421	33.5	36.1	35.0
Lombardy Overpass						
7:00 - 8:00 AM	5510	5402	5468	46.0	39.9	44.2
6:30 - 8:30 AM	10475	10230	10109	49.3	41.6	47.3
Calhoun Overpass						
7:00 - 8:00 AM	5403	5267	5387			
6:30 - 8:30 AM	10018	9849	9960			
System Average From SH 225 to Dumble Overpass						
7:00 - 8:00 AM				30.6	30.6	31.4
6:30 - 8:30 AM				36.4	35.8	36.7
Frontage Road Downstream of Telephone Entrance						
7:00 - 8:00 AM	498	595	395			
6:30 - 8:30 AM	690	789	533			

NOTE: 1) Speeds were measured downstream of the Wayside, Telephone, and Dumble exit ramps, respectively.

2) This refers to the two week closure period.

ramp before closure and during closure are shown in Figure 4. The "before" data shows a relatively high volume (1700 VPH) near 7:10 a.m., but the flow after 7:15 a.m. remains near or below 1300 VPH. With the ramp closed, the volume remained near the 1600 VPH. Between 7:00 and 8:00 a.m., the outside lane had a total volume of 1309 and 1612 vehicle for "before" and "during" closure, respectively, or an increase of more than twenty per cent with closure.

Freeway speeds were reduced about fifteen per cent upstream of the Griggs and Dumble entrance ramps. This was probably due to reduced merging operation at the ramp noses caused by the increased volume at the Griggs, Wayside, and Dumble ramps. A longer study would possibly permit motorists to adjust to the reduced merging operation and allow increased freeway speeds.

The general freeway operation was not significantly affected by the ramp closure. During the ten day study, there was a minor accident downstream of Cullen on each of two days and a one-minute stall over Griggs on a third day. On three other days, incidents before 7:00 a.m. affected the freeway operation after 7:00 a.m. As shown in Table 2, the average system freeway speed remained the same as "before". No visible shock waves between the Telephone and Lombardy overpasses were observed during the ten day study.

Ramp Operation

The summary of ramp data is shown in Table 1. Volumes at the Griggs and Wayside entrance ramps increased about five per cent, with minor delay increases. Although Griggs had twice as many ramp signal violations, these

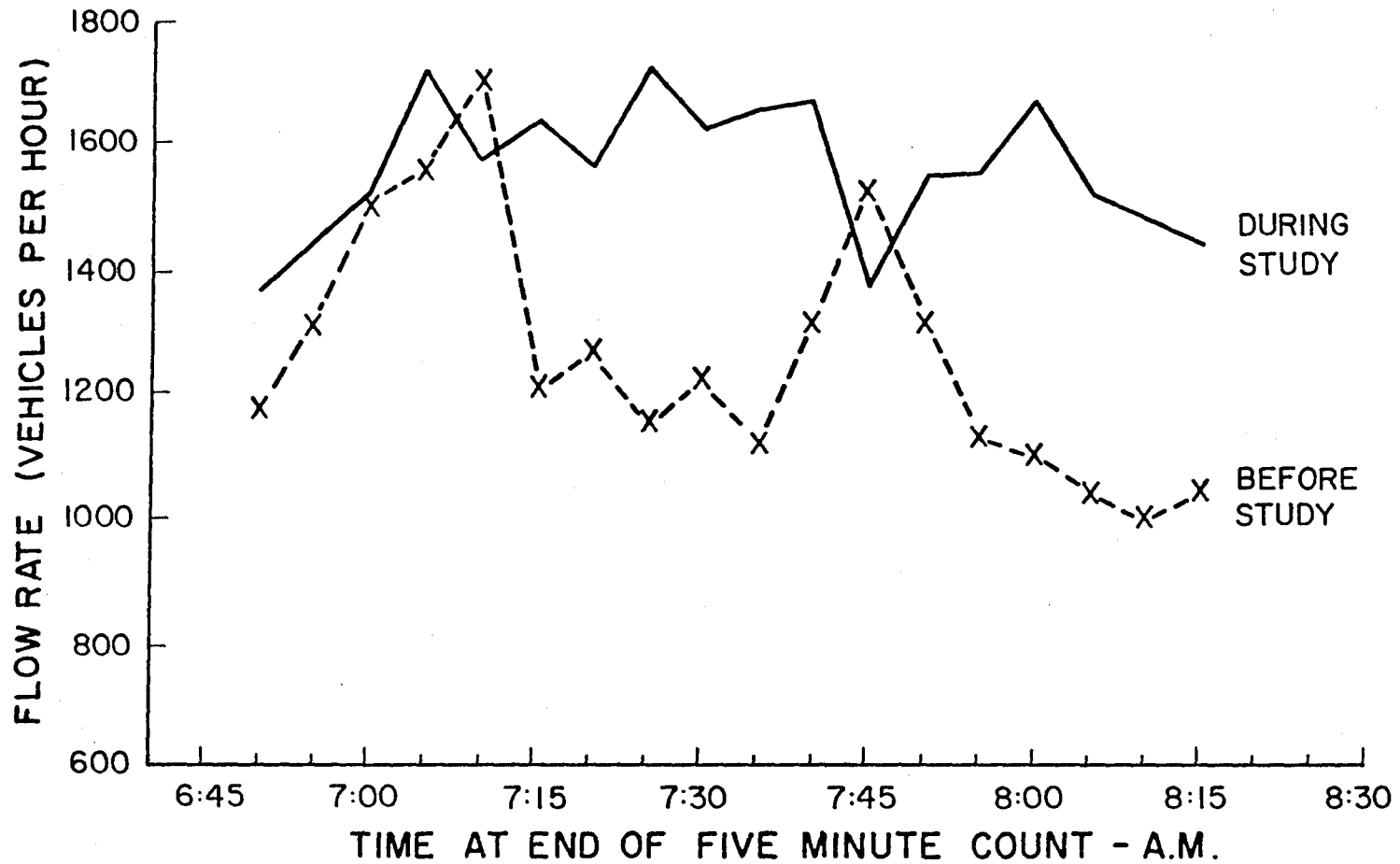


Figure 4. Comparison of five-minute volume counts on the outside freeway lane upstream of the Telephone entrance ramp (before and during closure).

were still less than five percent. As expected, Dumble entrance ramp volume increased by about forty percent (about 140 vehicles). Lengths of queues increased by several vehicles; however, the added delay was only about one minute. Initially, a significant increase in ramp signal violations occurred, but this was reduced midway in the study by increasing the signal metering rate.

Due to the proximity of the Dumble exit ramp to the Dumble entrance ramp, congestion resulted on the frontage road. On the first day of closure, the entrance queue frequently blocked the exit ramp. This was partly eliminated by increasing the metering rate, so blockage occurred only a few minutes of each peak period. As shown in Table 2, the volume over the Calhoun overpass was less than the Lombardy overpass. Since the capacity for both overpasses is similar, added ramp volume at this point did not cause the downstream freeway to be overloaded.

Diversion from Telephone Entrance

The "before" volume at the Telephone entrance ramp was 290 vehicles between 7:00 and 8:00 a.m. and 220 vehicles between 6:30-7:00 and 8:00-8:30 a.m. During the study, 215 vehicles used the ramp between 6:30-7:00 and 8:00-8:30 a.m. Therefore, there was no increased usage on the ramp before the ramp closure or after it was opened. Between 7:00 and 8:00 a.m. the Griggs and Wayside entrance ramps had an increase in volume of about 30 vehicles. Likewise, the Dumble ramp increased about 140 vehicles. Therefore, out of the 290 vehicles normally using the Telephone entrance ramp, 170 used other ramps. Between 7:00 and 8:00 a.m., trains blocked the frontage road on three days during the study:

April 27 - 7:07 to 7:05, 7:30 to 7:31

May 4 - 7:47 to 7:51

May 5 - 7:35 to 7:37

Therefore, delay on the frontage road caused by trains was insignificant.

Volume counts on Telephone Road northbound did not show an increase in traffic flow. Therefore, 120 vehicles normally using the Telephone ramp were not counted. It was assumed that they found another way to reach their destination. The "after" volume count at the Telephone entrance ramp between 7:00 and 8:00 a.m. was 40 vehicles less than the "before" counts. In a similar analysis, the Dumble entrance ramp had an increase of 30 vehicles that may have been diverted from the Telephone ramp. It is not known if this apparent diversion was due to the ramp closure, or if it will be permanent, since many other factors are apparent.

FINDINGS AND RECOMMENDATIONS

Findings

- Freeway flow decreased slightly.
- Speeds over the Telephone overpass increased.
- Speeds upstream and downstream of the Telephone overpass decreased.
- Average system speed from SH 225 to Dumble did not change.
- Shock waves moving upstream from Lombardy overpass were eliminated.
- Delays at ramps increased by about one minute, and railroad crossing blockage was insignificant.
- Half of the Telephone ramp motorists appeared to use the Dumble ramp.
- Added delay due to travel on the frontage road was between two to five minutes.
- The total delay to ramp motorists was small and probably not noticeable to most individual motorists.
- During the study, the Surveillance Office did not receive any citizen complaints about the closure, even though the telephone number of the office was included in the handout.

Discussion of Findings

The results listed above indicate at first glance that the ramp closure had little or no effect on the total travel of all motorists included. In fact, some of the findings, such as average speeds upstream and downstream of the ramp closure area, appear to be negative. The decrease in volume at the bottleneck sections was another disappointing finding. But before this control technique is labeled a failure, certain conditions should be reviewed.

First, the starting of Daylight Savings Time on the first day of the study must have had some effect on operations. This period would have been avoided if possible, but certain factors prevented any further changes in schedule (the study was scheduled for earlier in the year).

Secondly, the University of Houston had a significant effect on the traffic patterns of the Gulf Freeway. The University began a special time schedule for examination periods immediately after the ramp closure study, negating some of the "after" studies.

Finally, the design of the study to include only two weeks of data is suspect, since many things can and do happen to reduce the number of usable study periods. The vehicle stalls, accidents, and other less noticeable events that occur daily on the freeway cause large variations in the data so that small, subtle changes are difficult or impossible to detect.

Despite the inconclusive or negative findings of the study, other results call for a positive conclusion. First, the intuitive result of reducing input to a bottleneck section of freeway is improved and more consistent freeway operation. Long range studies of ramp metering have proven this.

Secondly, the fact that little or no measurable delay was experienced by the 300 displaced motorists is very encouraging. It implies that perhaps 500 or even 1000 vehicles could be displaced with only small increases in delay.

Third, the fact that no formal complaints were registered by these 300 displaced motorists substantiates the finding that no significant delays were encountered, and that other travel routes or time schedules are available.

Finally, the ability to carry out the physical closure, even in a manual mode, of the ramp with no noticeable problems shows the promise for more traffic responsive systems of closure that may be necessary in the future.

Recommendations

It is recommended that a series of studies, involving all of the entrance ramps to the Gulf Freeway Surveillance and Control area, be conducted to determine the conditions for which ramps should be closed, the length of time the closures should be made, the manner of effecting the closures, and the system for advising motorists of the closures.

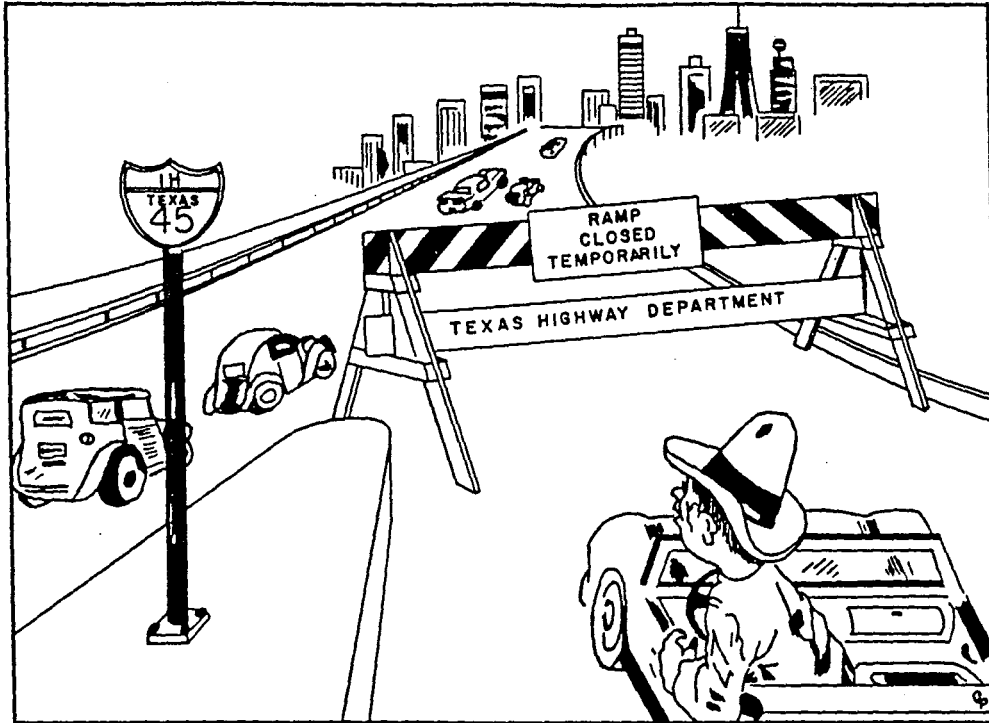
These studies should consider the situations of normal heavy flow during peak traffic, scheduled reduced capacity conditions due to construction and maintenance, and unscheduled events, such as vehicular stalls and accidents. A decision matrix for each ramp should be developed with the operational and managerial options outlined for the operating agency.

It is further recommended that additional control experiments of ramp closure be conducted as required to answer questions posed in the above discussions.

REFERENCES

1. Highway Capacity Manual - 1965. HRB Special Report 87, 1965.
2. Messer, C.J., Dudek, C.L., and Loutzenheiser, R.C. A Systems Analysis for a Real-Time Freeway Traffic Information System for the Inbound Gulf Freeway Corridor. Research Report 139-5, Texas Transportation Institute, 1971.

A P P E N D I X



WHAT : TELEPHONE RD. INBOUND ACCESS
RAMP TO BE CLOSED

WHEN : 7:00 - 8:00 A.M. WEEKDAYS
APRIL 26 - MAY 7, 1971

WHY : TRAFFIC STUDY

(SEE INSIDE FOR DETAILED INFORMATION)

TEXAS HIGHWAY DEPARTMENT
GULF FREEWAY SURVEILLANCE AND CONTROL PROJECT

Beginning April 26, 1971, and continuing until May 7, 1971, the Telephone Road Entrance Ramp will be closed weekdays between the hours of 7:00 and 8:00 a.m. Although studies have shown that the permanent closure of this ramp during the a.m. peak period will materially aid traffic movement on the Freeway, this study will enable us to determine if closure of ramps during certain peak periods is a practical approach to improved traffic operation on the total facility.

Motorists normally using this ramp may select one of several ways to obtain access to the Freeway, or they may wish to divert to the arterial street system. Access to the Freeway may be obtained through one of the other metered ramps, such as Griggs Road, Wayside Drive, or Dumble Road Ramps. If the arterial street system is used, we would suggest Telephone Road to Leeland or Polk Streets. We might also suggest Wayside Drive (OST) to Southpark Boulevard. The map below shows these alternate routes.

Travel times along alternate routes could be extended by train movements at train crossings; however, attempts will be made to eliminate or reduce the number and effect of train movements during this period.

We regret the inconvenience to you, but you can be assured that every effort is being made to improve the total transportation problem and provide Houston with a safe, more convenient, and more efficient freeway system.

Your cooperation in this traffic study will be appreciated. Should you have questions related to the closure of the Telephone Ramp or the alternate routes, please call 923-5910.

