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16. Abstract

Ramp metering is effective for improving freeway operations by reducing the traffic input to the freeway. For ramp metering control, there is a minimum rate for vehicles entering the freeway. If the control rate is set below this level, motorists begin to violate the metering signals, and the ramp flow rate is increased. To reduce traffic input below the minimum metering rates, positive ramp closures are studied in this report. The results were that freeway operation improved, and ramp traffic suffered only minimum added delay. A more automated system of ramp closure should be considered for better and more responsive operation to traffic conditions in bottleneck areas.

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STUDY OF TRAFFIC RESPONSIVE RAMP CLOSURE CONTROL

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Research Report 165-11

Development of Urban Traffic Management and Control Systems

Research Study Number 2-18-72-165

Sponsored by
The Texas Highway Department
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TEXAS TRANSPORTATION INSTITUTE

Texas A&M University
College Station, Texas

August 1972

ABSTRACT

Ramp metering is effective for improving freeway operations by reducing the traffic input to the freeway. For ramp metering control, there is a minimum rate for vehicles entering the freeway. If the control rate is set below this level, motorists begin to violate the metering signals, and the ramp flow rate is increased. To reduce traffic input below the minimum metering rates, positive ramp closures are studied in this report. The results were that freeway operation improved, and ramp traffic suffered only minimum added delay. A more automated system of ramp closure should be considered for better and more responsive operation to traffic conditions in bottleneck areas.

SUMMARY

This report is a study of positive ramp closures to reduce traffic input to a freeway bottleneck area during peak traffic periods. This study is similar to Project Report 139-9 entitled "The Effects of Entrance Ramp Closure of a Freeway Operation During Morning Peak Periods," in that the objective was to improve overall operation by further reducing traffic input to the freeway. However, the principal difference is that this study investigates the application of variable ramp closures based on real-time traffic data collected from the freeway.

Two dominant bottlenecks on the Gulf Freeway are the Lombardy overpass and Cullen entrance ramp. To reduce the demand at the Lombardy overpass, Griggs, Wayside, and Telephone entrance ramps were closed on weekdays for short times between the hours of 6:45-8:15 a.m. Similarly, the Cullen entrance ramp was closed in order to reduce demand in that area of the freeway. The following findings are based on the evaluation in this report:

- Freeway speeds and volumes increased at all locations along the freeway.
- Shock waves, normally propagated at the bottlenecks, were not observed during the study.
- Freeway congestion cleared much earlier than usual.
- Diverted motorists experienced delays of two to seven minutes.
- The Surveillance Office received some complaint calls, but it also received many compliments.

Implementation

Installation of ramp closure gates, in addition to ramp metering signals, would prove to be beneficial to freeway systems. The use of ramp closure gates would facilitate future traffic responsive studies. The following recommendations are made:

1. A more detailed study should be conducted using ramp closure gates.
2. A longer study with ramp closure in operation for an indefinite period of time would provide the vital data needed for a traffic responsive system of control.
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

Freeway ramp control systems have proved effective in increasing the level of service on urban freeways. One such system is ramp metering, a regulatory form of control, which adjusts traffic flow on ramps and improves the merging operation into the freeway. Even with ramp metering, freeways still have traffic demands that exceed the capacity of bottleneck sections. At these bottlenecks, shock waves move upstream causing an increase in the density of traffic throughout the system and resulting in undesirable levels of service. To improve operations, a system of positive ramp closure has been studied that will further reduce upstream traffic demands, thereby improving the level of service and peak period operations.

Situation on the Gulf Freeway

One bottleneck location, the Lombardy overpass, has a five percent grade at the overpass which reduces capacities for the three inbound lanes from a theoretical capacity of 6000 vph to less than 5400 vph (1). Entrance ramp traffic adds to upstream freeway flow and causes demand to exceed the capacity of Lombardy overpass for short time periods. The restriction of flow causes congestion between the Telephone and Griggs overpasses and an undesirable level of service upstream of Telephone overpass. (See Figure 1.)

The freeway area at the Cullen entrance ramp is a second major bottleneck section. The primary cause of congestion in this area is heavy volumes entering at Cullen ramp which has no control. When both the freeway volume upstream of

Cullen entrance ramp and the ramp volume approach peak values, speeds, and volumes decrease rapidly, causing shock waves to be generated upstream of the ramp. Once breakdown occurs, the operation upstream of the ramp usually does not regain a desirable level of service until after the peak period when traffic demands decrease.

To improve the total freeway operation, it was proposed that Griggs, Wayside, Telephone, and Cullen entrance ramps be closed for 15 to 20 minute periods between 6:45-8:15 a.m. (See Figure 2.) The closure would reduce input demand to the subsystems whenever traffic conditions in the field warranted closure. For example, if lane occupancy increases while traffic flow decreases at Lombardy overpass, this would indicate that congestion was developing and that closure of Telephone entrance ramp was necessary. Traffic would be diverted to alternate routes along the frontage road to the next entrance ramp downstream of the bottleneck.

Purpose of Study

The main objective of this study is to test the feasibility and acceptability of controlling four entrance ramps to the freeway by closures to reduce traffic demand to the subsystem to improve freeway operation. Closure of each ramp is initiated when visual evaluation of traffic operations from television monitors or electronic surveillance data indicated impending congestion. Short times of closure of each ramp reduce input demand, causing freeway speeds, volumes, and total travel time to improve throughout the system with minimum delay to those motorists diverted from the ramps.

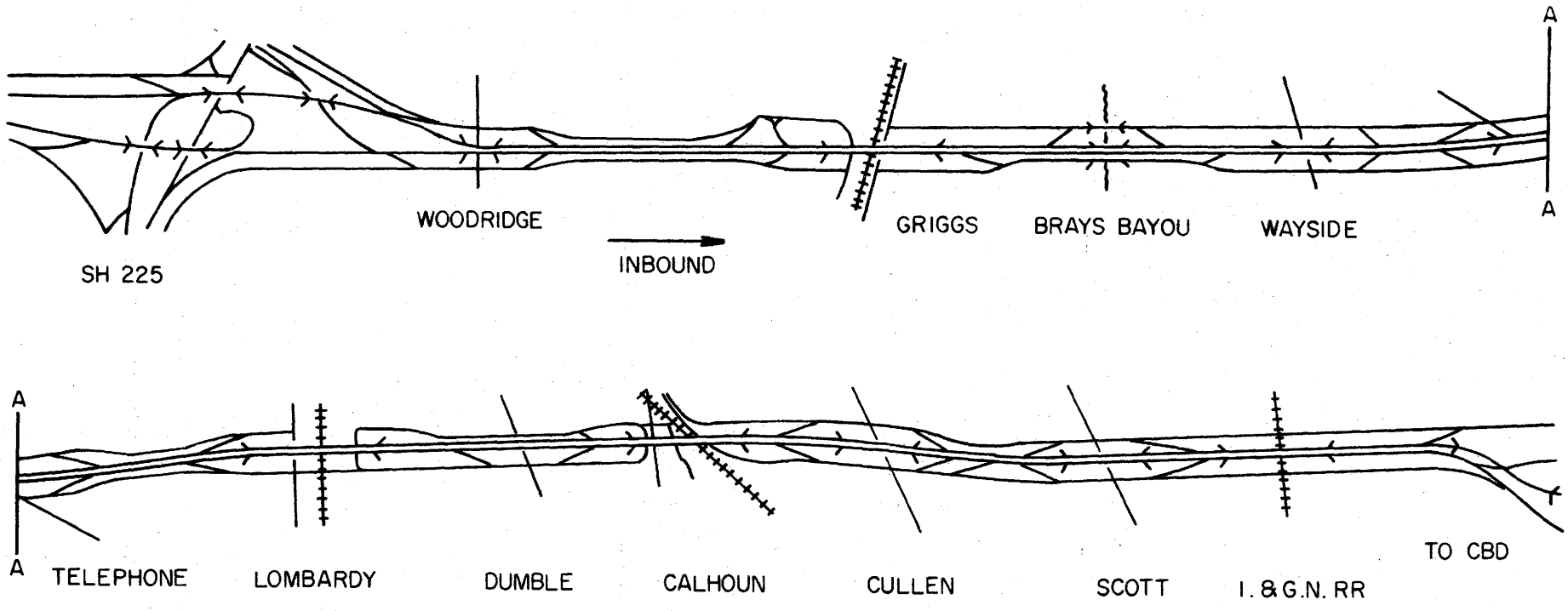

Figure 1. Map of the Gulf Freeway, Houston, Texas.

RAMP CLOSURE STUDY PROCEDURES

An analysis of the freeway was conducted in October 1972 as a before study to define normal freeway and ramp operations. During this period, alternate routes for diverted motorists were studied. Two weekdays before the ramp closures, a brochure (in the appendix) explaining the study and alternate routes was passed out to motorists at Griggs, Wayside, Telephone, and Cullen entrance ramps. The ramps were closed each weekday during the morning peak period from November 1, 1972 to December 21, 1972. Clock times for closures were different for each ramp since they were dependent on the variable parameters that indicated congestion. Appropriate data were collected during and after the study.

Background

To relieve the congestion at bottleneck locations, a reduction in demand is needed. One method of achieving this goal is by diverting traffic away from the bottlenecks to a ramp downstream where freeway capacity is available. Another alternative is simply to divert traffic to other routes away from the freeway.

Upstream of Lombardy overpass, there are three entrance ramps and two exit ramps whose cumulated total from 7:00-8:00 a.m. is plus 500 vehicles (1). The Lombardy overpass has a five percent grade which reduces capacity. Thus, the demand on those upstream ramps, when added to the freeway demand, exceeds the Lombardy overpass capacity. This problem can be solved by using Dumble entrance ramp, downstream of Lombardy, to accommodate the diverted traffic from upstream ramps. This is possible since approximately 600 vehicles exit at Dumble exit ramp and results in available freeway capacity at Dumble entrance ramp. If Telephone, Way-

side, and Griggs are closed for short periods of time, traffic is diverted, and the demand at Lombardy overpass is reduced. By closing Cullen entrance ramp for short periods of time, shock waves are prevented from moving upstream through the system.

The delay to diverted motorists was studied and found to be considerably less than the time saved by freeway motorists. The following diversion alternatives exist: (a) Dumble entrance ramp, (b) Griggs, Wayside, and Telephone entrance ramps before 6:45 a.m., (c) all ramps when opened after short closures, (d) Telephone Road northbound, and (e) Scott entrance ramp. The delay for most alternative routes would be minor. For example, a motorist diverted to the Dumble entrance ramp would have a total added delay of three to seven minutes.

Ramp Closure

The Griggs, Wayside, Telephone, and Cullen entrance ramps were closed by placing cones and barricades across the entrance ramps, as illustrated in Figure 2. Ramps were seldom closed at exactly the same time; therefore, closure times overlapped on all ramps. One man was assigned to each ramp to affect the closing and opening. Communications between the control center and the field were by shortwave radios provided by the Texas Highway Department.

The freeway parameters used to make the decision to open and close the ramps were taken from the computer, and visual evaluations of traffic slowdowns were observed on the closed circuit television system upstream of the ramps. The level of congestion at Lombardy overpass was used as the indicator for the closure of the Telephone ramp. The Cullen merge breakdown was used as the indicator for the closure of the Cullen ramp.

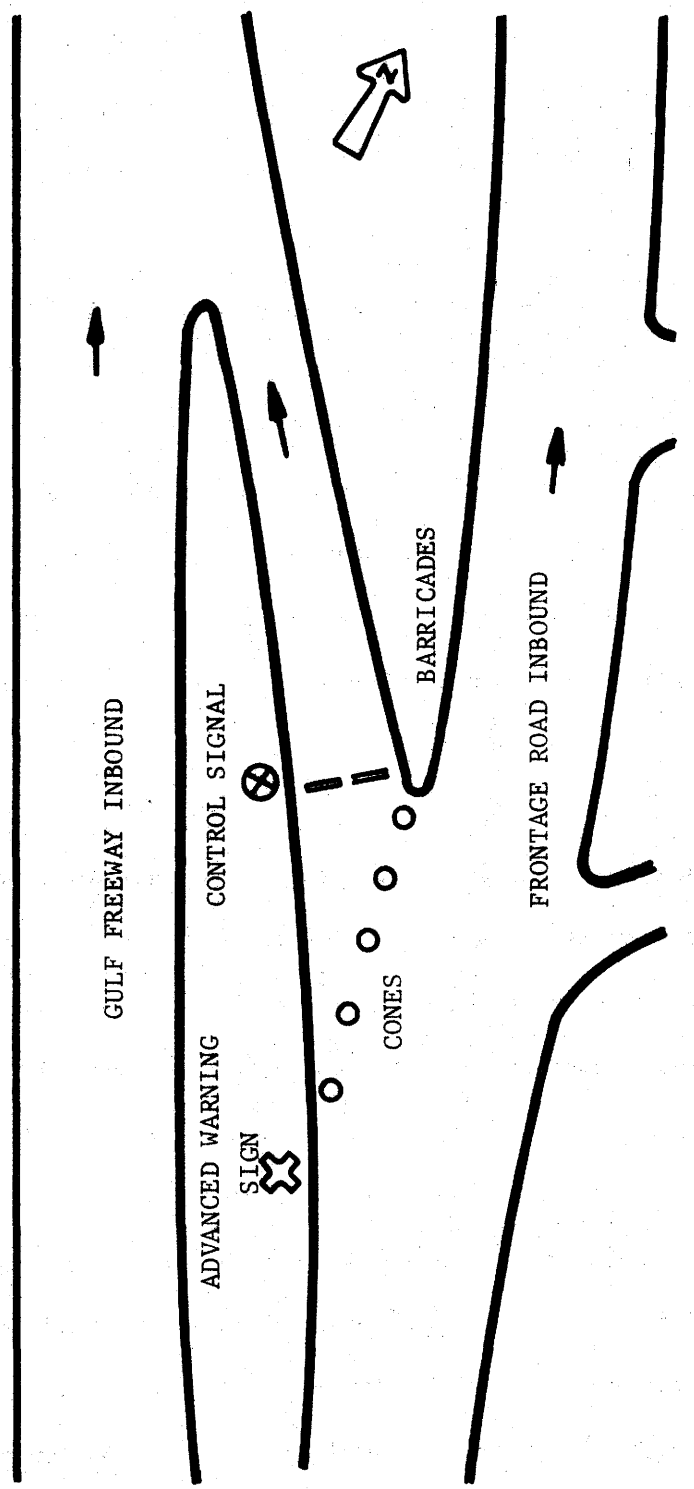

FIG. 2. METHOD OF CLOSING GRIGGS ENTRANCE RAMP

Complaints as well as compliments were received at the Surveillance Office. Some inquiries were made on which alternative routes would be most advantageous When the ramps were closed. Complaints about delays on the trip to work were also received. However, there seemed to be a balance between compliments and complaints.

ANALYSIS OF DATA

Freeway Operation

Comparative results of studies conducted before and during ramp closure showed an increase in freeway volumes and speeds as shown in Table 1 and Figure 4. There was a 1.5 percent improvement in freeway volumes, and a 20 percent improvement in freeway speeds. Some locations such as Griggs overpass, had volume increases of 5 percent.

Visual observations of the freeway indicated fewer shock waves than were observed previous to the ramp closure study. Shock waves that were generated at Lombardy and Cullen were seldom formed during closure; however, when the ramps were not closed at the appropriate times, small shock waves were observed. Earlier clearing times for excess traffic demand for the freeway were noted during the closure study. The freeway returned to free flow conditions as early as 7:40 a.m. on some days, as compared to 8:00 to 8:15 a.m. before the study.

Eighteen days in October were studied before the closure, and eighteen days in November were studied during the closure. The studies were used to evaluate time saved by using ramp closure as a method of freeway control. Analysis of both studies showed a total of 3109 vehicle hours saved by using the ramp closure between 7:00 a.m. and 8:00 a.m. The average delay to diverted traffic was 5 minutes. If 300 vehicles are assumed diverted between 7:00 a.m. and 8:00 a.m., in 18 days, the total delay would be 450 vehicle hours. Therefore, 2659 vehicle hours of travel time were saved for a daily average of 148 vehicle hours per day. At a rate of $4.50 per vehicle hour (2), the savings are $665 per day. The additional cost to close the ramps manually is approximately 10 man hours at $3.00 per man hour or $30 per day.

TABLE 1

SUMMARY OF FREEWAY DATA

Location	Number of Vehicles per Three Lanes		
	Before	During	After
Griggs Overpass			
7:00 - 8:00 AM	4994	5233	4904
6:30 - 8:30 AM	10165	10437	9940
Telephone (4)			
7:00 - 8:00 AM	5208	5275	5102
6:30 - 8:30 AM	10486	10555	10228
Lombardy Overpass			
7:00 - 8:00 AM	5150	5198	5173
6:30 - 8:30 AM	10236	10310	10165
Dumble Freeway			
7:00 - 8:00 AM	4639	4647	4700
6:30 - 8:30 AM	9102	9181	9183
NHB-T Freeway			
7:00 - 8:00 AM	5030	5127	4923
6:30 - 8:30 AM	9812	9912	9544

Location	Average Speed (MPH)		
	Before	During	After
Griggs Overpass			
7:00 - 8:00 AM	30	36	30
6:30 - 8:30 AM	34	39	34
Lombardy Overpass			
7:00 - 8:00 AM	34	40	33
6:30 - 8:30 AM	36	42	37
Cullen Freeway			
7:00 - 8:00 AM	30	37	36
6:30 - 8:30 AM	40	41	40

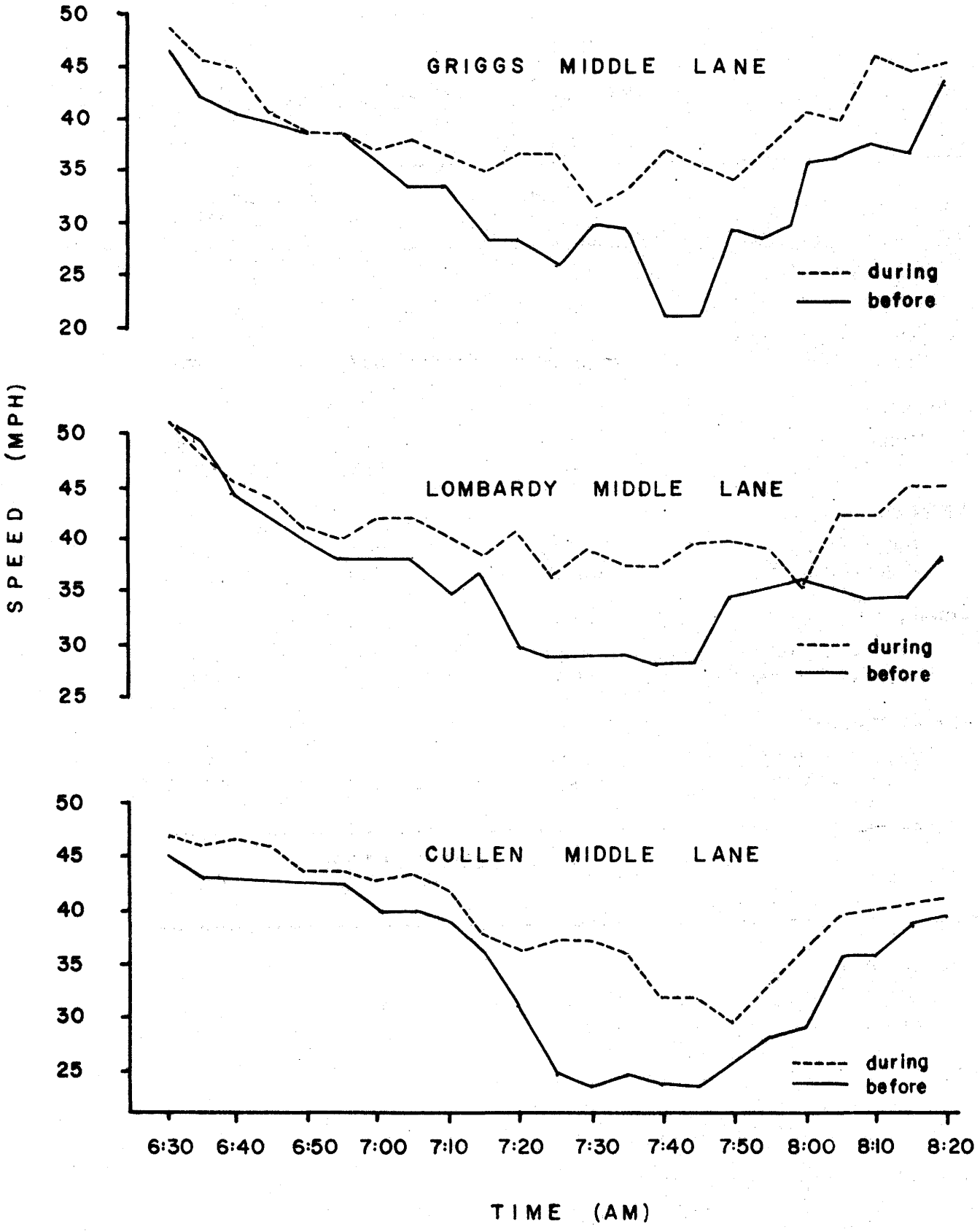

FIG. 3. SPEEDS BEFORE AND DURING CLOSURE

There are other costs associated with the operation, but they are assigned to other activities within the control center's operation. There are other savings in accident reductions, vehicle-operational costs, and commercial vehicle cost factors that have not been included in the analysis.

It is estimated that the installation of automatic devices to close the ramps on command from the computer would cost approximately $5,000 per ramp. Therefore, it would take two years to offset the manual cost of closure, but this system would be available for use 24 hours a day, rather than the original 5 hours per week suggested by the study. However, even the high costs of installation of the gates would be offset by the benefits of the system in approximately one month.

Although there was a reduction of the input of traffic demand to the freeway at the controlled (closed) ramps, this was more than offset by increases in traffic volumes at the other points of entry along the freeway. The analysis of the 6:30 to 8:30 volumes indicates that an increase in average speeds on the freeway lanes is even more significant. The following tables and graphs illustrate the improved operation of the freeway lanes in the study area. Table 1 shows the improved operation of the freeway lanes in the study area before, during, and after the ramp closure study.

Ramp Operation

The ramp volumes of ramps used in the study decreased as expected. Griggs and Wayside decreased 22 percent, and Telephone decreased 9 percent. Downstream of those ramps closed, the Dumble ramp volumes increased by approximately 20 percent. The Mossrose ramp volumes, upstream of the study ramps, increased by 12 percent. Ramp queues increased considerably at Dumble and resulted in added delay.

In a two-hour study of five days from 6:30-8:30 a.m., data before and during ramp closure were analyzed to determine the average number of diverted motorists. Two hundred and sixty-five cars were diverted from Griggs, Wayside, and Telephone. Dumble ramp had an increase of 124 vehicles; thus, 141 of those vehicles used other routes or trip time to travel to their destination. Approximately 47 percent of all motorists were diverted to Dumble entrance ramp, and 53 percent used other alternative routes. Five 'good' days were used in Table 2, and five 'bad' days were used in Table 3 to illustrate the change in demand due to ramp closure.

TABLE 2

CHANGE IN DEMAND DUE TO RAMP CLOSURE

6:30-8:30 AM VOLUMES

	Oct.'72 (Metered Ramps)*	Nov.'72 (Closed Ramps)*	Nov.-Oct.
Fwy @ 225	7661	8030	+369
Fwy @ Woodridge	8989	9368	+379
Fwy @ Griggs (4)	9504	9877	+373
Fwy @ Telephone (4)	10,573	10,627	+ 54
Fwy @ Telephone (3)	10,248	10,353	+105
Fwy @ SHB&T	10,307	10,410	+103
Fwy @ Dumble	9152	9230	+ 78
225 On	1485	1576	+ 91
35 On	1074	1139	+ 65
Woodridge On	811	817	+ 6
Mossrose On	554	541	- 13
Griggs On	545	427	-118
Wayside On	493	387	-106
Telephone On	445	406	- 39
Dumble On	673	797	+124
35 Off	893	1014	+121
Woodridge Off	357	369	+ 12
Mossrose Off	117	80	- 37
Wayside Off	7351	781	+ 46
Telephone Off	324	342	+ 18
Telepsen Off	257	260	+ 3
Dumble Off	1154	1179	+ 25

*5 Good days in October (12, 27, 18, 20, 9) and 5 good days in November (29, 9, 10, 21, 17) were averaged for the table above. Good day = no incidents, clear, dry.

TABLE 3

CHANGE IN DEMAND DUE TO RAMP CLOSURE

6:30-8:30 AM Volumes

	Oct.'72 (Metered Ramps)*	Nov.'72 (Closed Ramps)*	Nov.-Oct.
Fwy 225	7096	7338	+242
Fwy @ Woodridge	8263	8604	+341
Fwy @ Griggs (4)	8889	9267	+378
Fwy @ Telephone (4)	9960	10,086	+126
Fwy @ Telephone (3)	9666	9855	+189
Fwy @ SHB&T	9766	9975	+209
Fwy @ Dumble	8677	8936	+259
225 On	1309	1345	+ 36
35 On	989	962	- 27
Woodridge On	840	799	- 41
Mossrose On	550	605	+ 55
Griggs On	589	491	- 98
Wayside On	483	407	- 76
Telephone On	456	435	- 21
Dumble	665	745	+ 80
35 Off	844	844	0
Woodridge Off	312	295	- 17
Mossrose Off	104	85	- 19
Wayside Off	659	646	- 13
Telephone Off	294	286	- 8
Telepsen Off	230	241	- 11
Dumble Off	1096	1039	- 51

*5 bad days in October (5, 10, 30, 23, 16) and 5 bad days in November (3, 6, 1, 13, 27) were averaged for the table above. Bad day = incidents, cloudy, wet.

FINDINGS

The following conclusions are based on the evaluation presented in this report:

- Freeway speeds increased at all locations along the freeway, particularly where the ramps were closed. The average freeway speed for the system increased by 20 percent. (See Figure 3.)

- Shock waves normally propagated at the Lombardy overpass and at Cullen entrance were not observed during the closure study.

- The freeway cleared earlier during the closure study than during a similar period. Figure 4 illustrates improvement in total travel time during the ramp closure study.

- Volumes increased slightly throughout the system. Particular locations where volumes were low before closure, such as Griggs overpass, had significant increases in volumes during the closure study.

- Diverted motorists from Griggs, Wayside, and Telephone ramps suffered increased delays of 2 to 7 minutes. Of the many telephone calls made to the surveillance office, there were an equal number of compliments and complaints.

- Ramp closure control proved to be effective in reducing upstream traffic demands thereby improving the level of service during the peak period operation. The system kinetic energy illustrated in Figure 5 shows improvement in peak period operation.

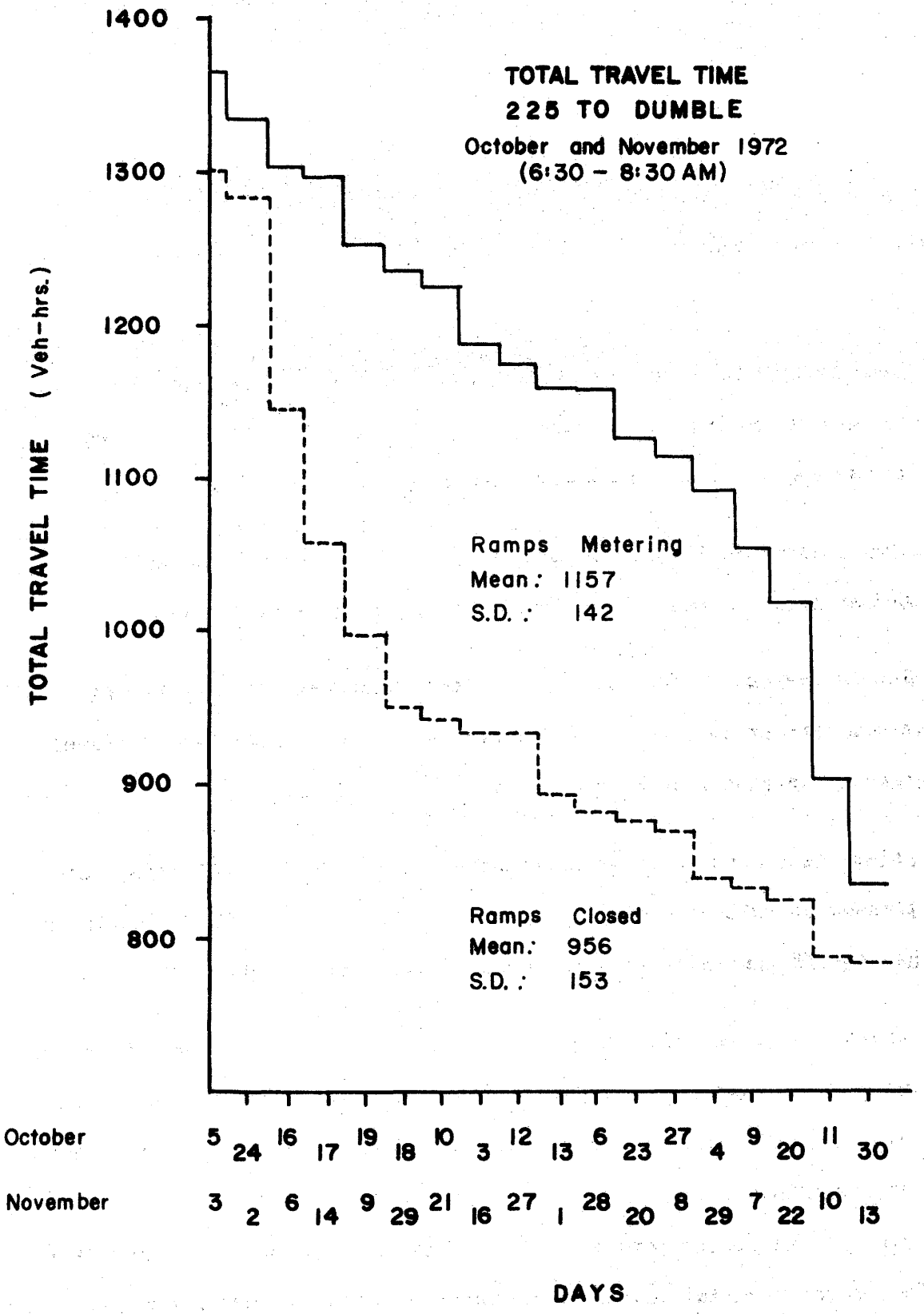

FIGURE 4. TOTAL TRAVEL TIME FROM 225 TO DUMBLE

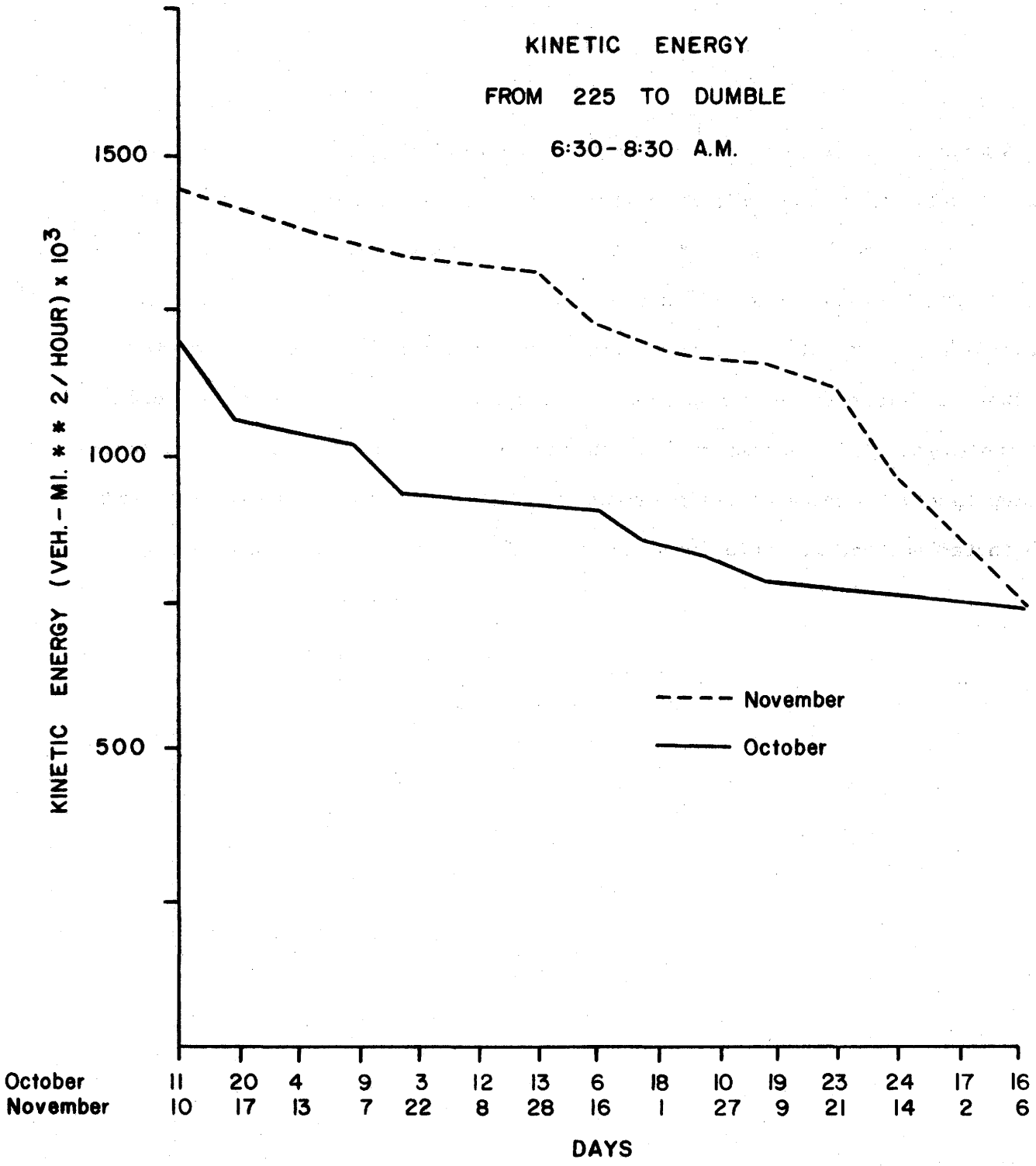

FIGURE 5 — TOTAL SYSTEM KINETIC ENERGY FROM 225 TO DUMBLE

RECOMMENDATIONS

A more detailed study should be conducted on the feasibility of automatically initiating closure and advising motorists of the closure. A program was developed by which parameters at different locations are analyzed, and effective ramp clsoure times per ramp obtained. Further analysis of data collected during the closure study is needed to determine appropriate parameter values for a successful ramp closure. A decision matrix for each ramp could be developed with the operational and managerial options outlined for the operating agency. Altogether, a more automated system of ramp closure could easily be installed, and it would prove to be a benefit to freeway systems.

RAMP CLOSURE GATES

Special specifications for ramp closure gates have been devised by the Texas Highway Department. The following description of operation as stated by the Texas Highway Department reads:

"The gate will be placed in the horizontal position when traffic conditions on the freeway lanes indicate that additional input volumes from this ramp would be detrimental to traffic operations. The gate will remain in a closed position for a mandatory minimum time (approximately 5 minutes), and for an extended time that is established by freeway ramp conditions.

It is anticipated that each ramp gate will be cycled, on the average, 2 to 5 times a day, and that the gate will remain in the horizontal position from 15 to 30 minutes. Therefore, cycle rates of 1,000 to 1,500 closures per year and closure rates of 500 to 750 hours per year are conservative estimates of the usage of the ramp closure gates."

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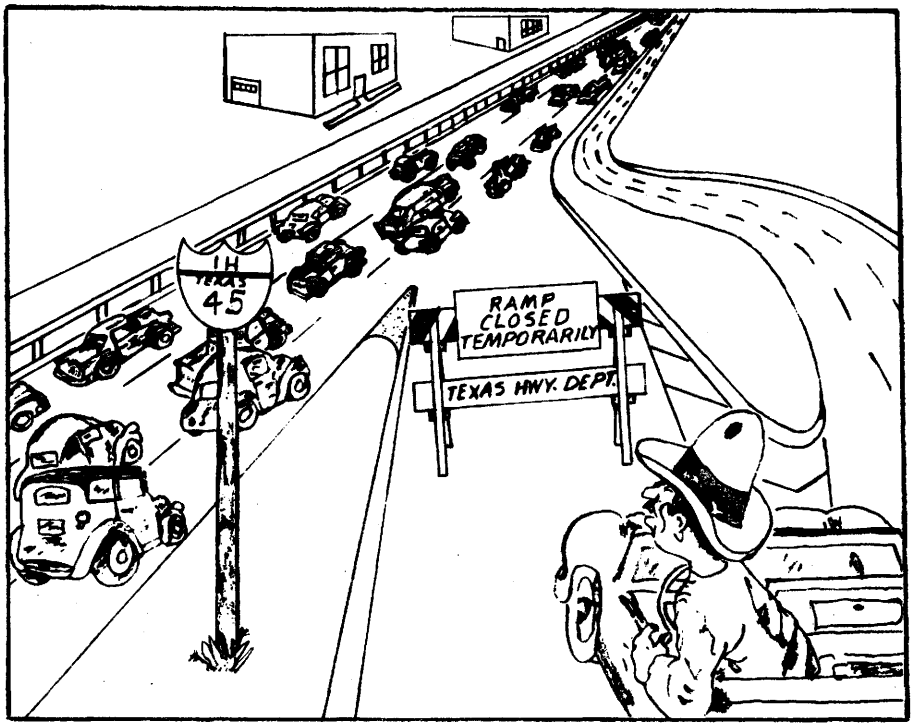
1. Loutzenheiser, R. C. The Effects of Entrance Ramp Closure on Freeway Operation During Morning Peak Periods. Research Report 139-9, Texas Transportation Institute, 1971.

2. Pittman, Mary Ann and Loutzenheiser, R. C. A Study of Accident Investigation Sites on the Gulf Freeway. Research Report 165-1, Texas Transportation Institute, 1972.

A P P E N D I X



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)

TEXAS HIGHWAY DEPARTMENT
GULF FREEWAY SURVEILLANCE
AND CONTROL PROJECT

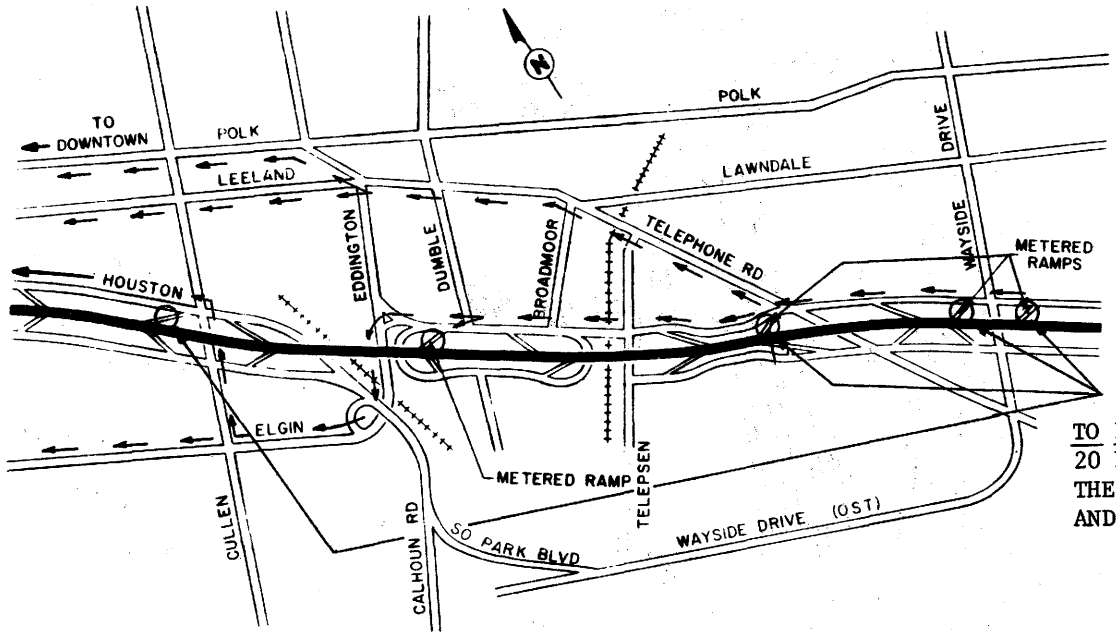
Beginning November 1, 1972, the Griggs Road, Wayside Drive, Telephone Road, and the Cullen Drive Entrance Ramps will be closed for approximately 20 minutes between the hours of 6:45 and 8:15 a.m. on weekdays. The exact times of which the ramps will be closed and opened can not be scheduled since they will be determined each day by traffic conditions on the freeway as monitored by a traffic controller.

If you approach one of these ramps when it is closed, proceed down the frontage road and take one of the alternate routes marked on the map below. You will always be able to enter the freeway by one of the ramps marked on the map, but use of one or more arterial street routes to bypass this section of the freeway should be considered.

Your trip time when using the alternate routes will not be significantly greater than when entering the freeway at one of these ramps when freeway conditions call for the closure of the ramps.

We regret any 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 safer, more convenient, and more efficient freeway system. Your assistance and cooperation in this project will be appreciated.

Should you have questions related to the closure of these ramps, or the alternate routes available for use, please call 923-5910. Also, any problems involving unusually high traffic delays should be reported.



TO BE CLOSED FOR
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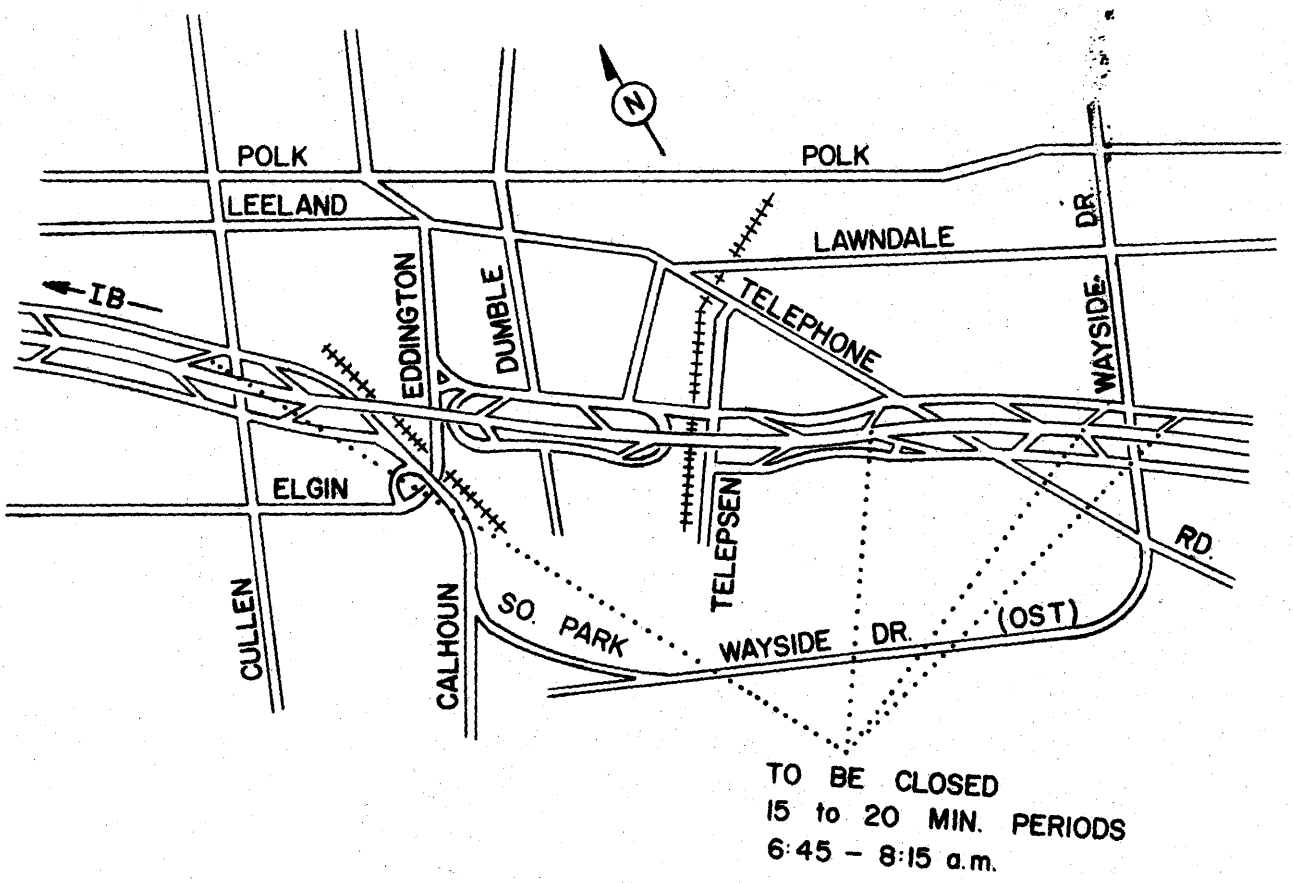
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SO. PARK
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(OST)
TO BE CLOSED
15 to 20 MIN. PERIODS
6:45 – 8:15 a.m.