AN EVALUATION OF FREEWAY RAMP CLOSURE

by

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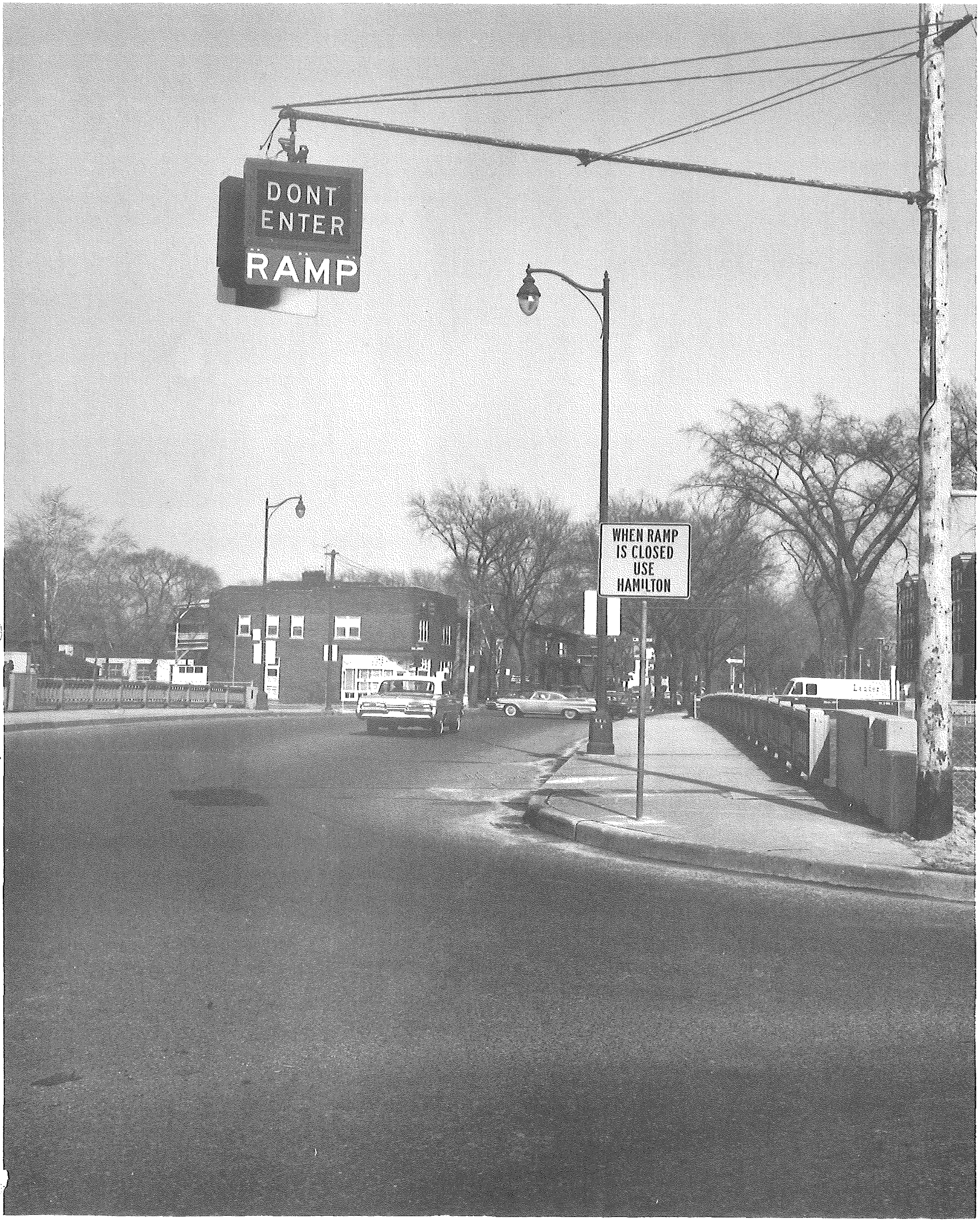
Introduction

The John C. Lodge Freeway Traffic Surveillance Research Project has, as one of its principal objectives, the development of a variable traffic control system for freeways which will permit a more efficient utilization of this type of road facility. The intent of the research is to develop a control system which will reduce congestion, improve capacity, and provide a safer travel environment. Should these benefits be realized, they will produce cost savings of considerable proportions. Such savings could be compared to construction costs necessary to achieve similar benefits. Should the traffic control system prove the more efficient this fact becomes positive evidence that the money would be better placed in this area rather than in construction.

The Project has developed three types of variable traffic control on the freeway. One is the lane signal system which tells the motorist when to use or not to use a driving lane. The second is a variable speed control which advises the motorist of the proper driving speed. The third is ramp entrance control which permits the opening or closing of a ramp. Ramp control and its effects are the subjects of this paper.

The Ramp Control Signals

There are nine entrance ramps in the three-mile study area of the John C. Lodge Freeway. Each was placed under the control of a ramp signal bearing the message "Don't Enter". (See Photo I) The signal is a blankout type device which shows the message only when the signal is illuminated.


DONT
ENTER
RAMP
WHEN RAMP
IS CLOSED
USE
HAMILTON

Preliminary tests to measure the effectiveness of the ramp signals were conducted in the spring of 1960. An experimental ramp signal was installed at the Trumbull Avenue entrance ramp to the westbound lanes of the Edsel Ford Freeway. The installation consisted of two back-to-back signals mounted on a mast arm so they would be visible to both directions of oncoming Trumbull Avenue traffic. The results of this experiment were documented in a paper by Richard D. Belprez and Conrad L. Dudek.

In general, the experiment proved that motorists read the signal when placed in a visible location. But while the motorists read the signal, they did not always obey it. Several drivers were observed who looked intently at the signal and then looked around to determine if the ramp was still usable. If it was clear they entered the freeway.

The "sheep" effect was also noted during this experiment. When one motorist entered the ramp against the signal message, others would follow. But if the lead motorist in a platoon obeyed the signal, the remainder of the motorists did likewise. The fact that motorists did not always obey the signal was accepted as quite natural in view of the fact that there had been no publicity about the test and no enforcement efforts were made.

A further consideration of the ramp signal test was to learn whether a ramp can be controlled by a signal only. Without this knowledge there would be little evidence to support the expense of installing such devices as automatic gates, which would be cheaper than law enforcement but considerably more costly than a signal system.

Proper mounting of ramp signals plays a very important part in the success of ramp control. Each approach direction to the ramp must have a signal plainly visible to the motorist and the ramp must be identified with the signal. An overhead mount is most appropriate for the majority of locations; however, pedestal mounts were used in certain areas to provide better visibility.

Description of Experiment

Installation of a signal at each ramp provided an opportunity to study the effects of ramp control on freeway traffic by a total closure of a ramp during selected periods. No attempt was made to meter ramp traffic during this experiment.

A continuing study is being made on the Lodge Freeway to determine volume-speed relationships by lanes for various locations. The results indicate that single point measurements of freeway traffic do not permit an accurate prediction of impending breakdowns. It is only by considering the nature of downstream traffic and comparing it to the traffic being discharged from the area that a reasonable prediction can be made. For example, a high-volume, high-speed platoon of traffic moving into an area where a lower speed prevails can result in a complete traffic breakdown. This same platoon, moving into an area which is discharging traffic as fast as it is received will cause no difficulty. If this knowledge is added to the fact that the highest traffic volumes on a freeway occur when traffic is moving in a fluid condition, the benefits of ramp control become apparent.

Experience has proved that fluid levels of traffic can be maintained as long as no interference occurs in the traffic stream to cause traffic to break speed and, consequently, reduce freeway capacity. When large volumes of traffic are using the freeway, headway between vehicles is reduced to a point that when a disturbance occurs there is not enough elasticity in the traffic stream to permit alteration in headway between vehicles. As a result, speeds must be reduced. This creates the well-known "shock-wave".

One of the most frequent causes of disturbance in the traffic stream and breaks in vehicles speed is entrance ramp traffic. A vehicle entering the freeway will merge into a short gap between vehicles. But the original gap will then be lengthened as the entering vehicle drops back to acquire safe headway from the car ahead. J. H. Auer, Jr., in a paper titled "A System for the Collection and Processing of Traffic Flow Data by Machine Methods", showed that when gaps between vehicles shorten to an average of approximately three car lengths, lowering of speeds results because vehicles "back off" to obtain a more comfortable driving space.

The purpose of the ramp experiment was to prove that when headway between vehicles allowed high traffic volumes but no additional capacity for ramp traffic, closing ramps would preserve good freeway operation. The theory was that, if more cars used the freeway in a shorter period, there would be a smaller backlog of traffic in the central business area. This would benefit freeway traffic operation and actually minimize congestion on arterial streets. The John C. Lodge Research Project, adjacent to the central business district of Detroit, is ideally situated to study and evaluate the practical application of this reasoning.

Closing freeway ramps to entering traffic created a problem in public relations which had to be handled carefully. Lack of public understanding and support could have brought an end to the experiment. It was necessary to carefully select and sign alternate routes. On these, motorists could travel parallel to the freeway and either reach their destinations or enter the freeway downstream where reduction in volumes, due to discharge at exit ramps, permitted the addition of traffic without creating stoppages. Trail blazer signs were used to mark the alternate routes. These signs advised motorists how to proceed along the alternate route to reach the next entrance point on the freeway.

This left a problem in those cases where the second entrance ramp also was closed. A motorist would tolerate finding his first choice of a ramp closed and follow an alternate route. But if he was guided to a second closed ramp, he could become quite impatient. If this were repeated often enough, it would create a serious public relations problem. To prevent this difficulty, the trail blazer sign was designed so arrow on the sign could be changed manually to guide the motorist directly to an open ramp.

Design of Study

The initial ramp closure study was conducted during the week of March 4, 1963. There are nine entrance ramps in the study area, as shown in

Figure 1. Individual ramps and combinations of ramps were selected for closing during various time periods.

The selections were based on several considerations. Each entrance ramp was scheduled for at least one closure period. This was to provide comprehensive experience on the effects of various types of ramps on freeway traffic behavior. Peak traffic periods (7-9 a.m. for southbound traffic and 3-6 p.m. for northbound) were chosen since these were the times when ramp traffic has its most marked effects.

It was important to the results of the experiment to show the changing traffic characteristics created by ramp closure; therefore, three weeks before the ramp closing experiment, various traffic measurements were taken both on the freeway proper and on surrounding streets which could carry bypass traffic. Forty-eight locations were studied so that the traffic pattern, undisturbed by ramp closures, would be available later for comparisons. During these three weeks, freeway lane stoppages were also recorded for the peak traffic from 7 to 9 a.m. and from 3 to 6 p.m. Lane stoppages were recorded when caused by traffic volume congestion. Stoppages due to stalled vehicles and other incidents were recorded separately so they could be properly interpreted in the analysis of the experiment. Data gathered in advance of the experiment was used also to determine the proper placement of directional signs along the alternate routes that motorists would follow through the area when entrance ramps were closed.

Observations made during the two years prior to this study had pinpointed locations where trouble was likely to develop during peak periods. Ramps at or near these locations were selected for special attention.

During the morning rush period, when the southbound lanes carry the peak loads, the majority of slow-downs and stoppages occur in the first three camera fields south of the Davison Interchange. The principal congestion area is in the Camera 1 viewing field (Glendale). The southbound Lodge freeway is three lanes wide and receives both east- and westbound Davison ramps at this point. The westbound Davison ramp carries a relatively high volume of trucks and merges on the left side of the Lodge roadway. This adds to the congestion as the trucks change lanes moving toward the right lane of the freeway.

During the evening rush period (3-6 p.m.) one to two hundred stoppages commonly occur in the study section's northbound lanes. Congestion usually develops earliest in Camera 14 field immediately north of the Edsel Ford Interchange. Two ramps, each of two lanes, deliver traffic from the Ford freeway to the three lanes of the northbound Lodge. (These ramps have since been reduced to one lane each by paint markings and signing.)

In the reverse curve section through the Calvert Street-Chicago Avenue area, many stoppages occur regularly. They appear to be due to the geometrics and a short acceleration lane at the Chicago entrance ramp.

Scattered stoppages also occur regularly from Camera fields 8 through 12. Many of these are apparently caused by lane changing; vehicles entering at West Grand Boulevard and Seward ramps must move out of the shoulder lane before reaching Camera 9 field where this lane is signed for exits only. Additional numbers of vehicles in the same area change from the median lane to the shoulder lane in order to exit at Clairmount of Hamilton.

By noting the effects of the closure of individual ramps, combinations of ramps were selected for closing as the experiment progressed.

Approximately two-thirds of the length of the freeway in the study area is paralleled by service drives which offer convenient alternate paths to the next available entrance. In the areas without service drives, motorists were directed to the most accessible arterial street which would carry them to the open entrance ramps. Figure 1 shows these routes.

The week of March 4, 1963, was used to study the effects on both freeway and surface street traffic by ramp closure. Dispersal of ramp traffic after departing from a closed entrance ramp was carefully noted to determine the new travel paths and the ability of the surface streets to handle the additional load. Each ramp was closed at least once to study the dispersal pattern resulting from such single closures. Beyond this, ramp closures were chosen which seemed to offer the best prospects for maintaining smooth and maximum flow on the freeway.

To assure obedience to the "Don't Enter" signals, police officers were stationed at the head of the entrance ramps. This positive closure was necessary in order to measure the full impact of traffic diverted to surface streets.

JOHN C. LODGE FREEWAY ON-RAMP STUDY AREA PLAN SHOWING ALTERNATE ROUTES

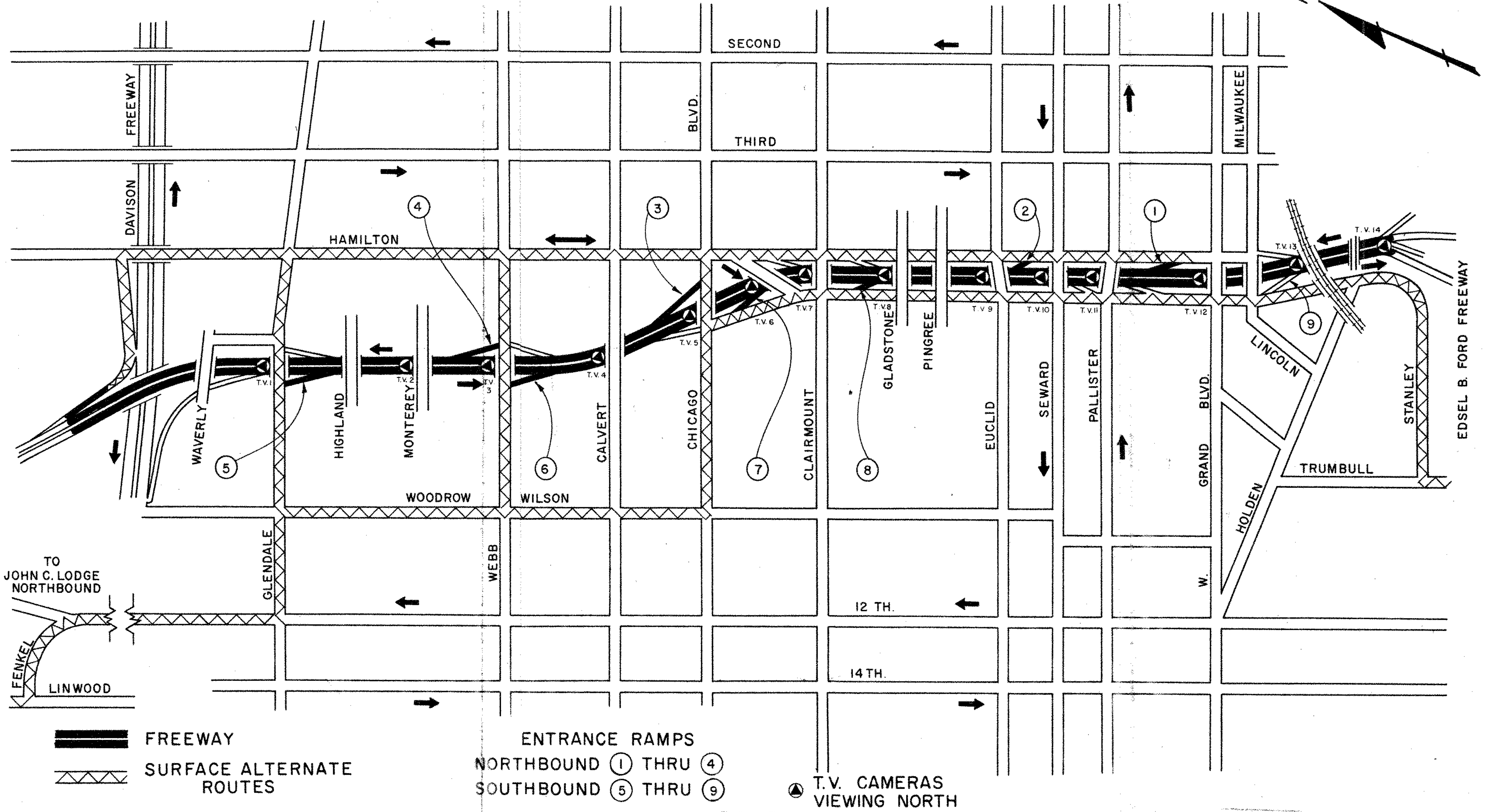


FIGURE I

Vehicle stoppages on the freeway and travel times of a number of individual vehicles were recorded by lane throughout the study area. This information was acquired by stationing observers at television monitors in the TV Control Center of the Project. Lines were placed on the TV monitors to provide reference points for the measuring of travel times. Lane changes were recorded in several camera views in each direction covering the areas most critical in their relationship to the ramps being closed. Volume counts were continued, as were the recording of point speeds by sensing equipment at Chicago Avenue or Calvert Street.

The first day of the study week was devoted to familiarizing a number of new men with their duties in gathering data for the study. For this reason, data for the first day is not included with the other four days of the study week.

Freeway Traffic Flow Analysis

During the study week, the closing of ramps at peak traffic periods substantially benefited freeway traffic movement. The comparison of freeway traffic volumes for the peak travel periods of 7-9 a.m. and 3-6 p.m. is very important to an evaluation of the ramp closure study. Table I compares 2-hour southbound volumes and 3-hour northbound volumes in the three weeks prior to ramp closure and during the one-week period when ramp closures were in effect. Southbound traffic was inbound to the central business district in the mornings; northbound traffic was outbound in the afternoons. These peak traffic situations are used in the comparisons in Table I. Limitations of

TABLE I

FREEWAY VOLUME COMPARISONS

	3-Hour Northbound Volumes 3:00 - 6:00 p.m.			2-Hour Southbound Volumes 7:00 - 9:00 a.m.		
	Previous 3-Week Average	Study Week 3-5-63	% Increase	Previous 3-Week Average	Study Week 3-5-63	% Increase
Tuesday	16490	17320	5%	10998	11521	4.8%
Wednesday	15378	15954	4%	10807	11456	6%
Thursday	16248	17067	5%	9998	11365	13.7%
Friday	16575	17155	3.5%	10845	11542	6.5%

instrumentation prevented comparisons of both travel directions simultaneously, but would not have influenced the validity of the results. Unusual incidents occuring in the direction of lighter travel which would have influenced driver behavior in the peak direction would have been noted by television surveillance.

Freeway volumes were, in all instances, higher during the ramp closure week than during the non-closure periods. These figures are distorted to the disadvantage of ramp closure; in some instances, traffic normally using the freeway by-passed freeway traffic sensors under certain ramp closure conditions. A more perfect experiment would have freeway sensors at the beginning and end of the ramp closure area. Again, equipment limitations did not permit this. But such an arrangement will be considered in future experiments.

Southbound traffic volumes increased from 4.8 to 13.7 percent. Northbound volumes increased from 3.5 to 5 percent.

Since stoppages on a freeway are definite indications of poor operating conditions, Table II was designed to compare stoppages with and without ramp control. For southbound traffic, there was a reduction in stoppages in the 7-9 a.m. period ranging from 22 to 54 percent. Considering the ramp closure periods only, the reduction in stoppages was even more marked, ranging from 26 to 65 percent. Northbound traffic had a reduction in stoppages ranging from 51.5 to 92.5 percent during the 3-6 p.m. interval. Comparing ramp closure periods only, the reduction in northbound stoppages ranged from 65 to 92.5 percent.

TABLE II

FREEWAY LANE STOPPAGE COMPARISONS *

	Northbound				Southbound			
	Lane Stoppages 3:00 - 6:00 p.m.		% Difference		Lane Stoppages 7:00 - 9:00 a.m.		% Difference	
	Previous 3-Week Average	Study Week 3-5-63	3-hour Study Period	Ramp Closure Periods Only	Previous 3-Week Average	Study Week 3-5-63	2-Hour Study Period	Ramp Closure Periods Only
Tuesday	67	33	Down 51%	Down 65%	43.5	34	Down 22%	Down 36%
Wednesday	114	26	Down 77%	Down 82%	67	31	Down 54%	Down 65%
Thursday	90	9	Down 90%	Down 90%	58	28	Down 52%	Down 54%
Friday	94	7	Down 92.5%	Down 92.5%	40.5	30	Down 26%	Down 26%

* Stoppages due to congestion only.

The stoppages were tabulated for the entire length of the study area. Under these circumstances, not only is the number of stoppages important, but also the extent of the stoppages. One stoppage extending a short distance can be far less critical than one stretching over a long distance. Table III compares the average length of stoppage waves in the period before ramp closure and the period after ramp closure. The reductions were highly significant, ranging from 28 to 86 percent with most nearer the higher figure.

An interpretation of Tables II and III indicates that ramp control not only reduced the number of stoppages but also reduced the area of the freeway over which they had influence.

Travel time of traffic moving through the study area was noted by observers viewing the television monitors. The results appear in Table IV. The table shows average travel speed through the study area by time of day and identifies the period during which designated ramps were closed. While not all ramp closures produced positive benefits, average speeds were higher during most ramp closing periods. To properly interpret Table IV, it is necessary to take a period during which a ramp is closed (shown in the left-hand portion of the table) and compare it with the period most nearly matching it (in the right-hand portion of the table).

During the critical morning period between 7:30 and 8:45 a.m., the average travel speed without ramp control was 27 miles per hour. By applying ramp control during this same period, average speeds up to 42 miles per hour were obtained. While direct comparisons of this kind are

TABLE III

LENGTH OF TRAVEL OF STOPPAGE WAVES COMPARISON

Day of Week	Time Period	Average Length of Travel in Feet		% Reduction
		Before Period	Study Week	
Northbound				
Tuesday	3:00 - 6:00 p.m.	4450	3190	28
	Ramp Closure Periods Only	5130	690	86
Wednesday	3:00 - 6:00 p.m.	5130	3190	38
	Ramp Closure Periods Only	3880	1030	73
Thursday	3:00 - 6:00 p.m.	4790	1140	76
	Ramp Closure Periods Only	3190	570	82
Friday	3:00 - 6:00 p.m.	2280	800	65
	Ramp Closure Periods Only	2280	800	65
Southbound				
Tuesday	7:00 - 9:00 a.m.	5980	1500	74
Wednesday	7:00 - 9:00 a.m.	580	350	40
Thursday	7:00 - 9:00 a.m.	2880	520	82
Friday	7:00 - 9:00 a.m.	4600	2880	37

TABLE IV

SPEED COMPARISONS

RAMPS CLOSED

Time Periods & Day of Week		Ramp	Average Travel Time Speeds (Lanes 1 & 2) (MPH)	Speed Range (MPH)
Northbound				
P. M.				
3:45-4:15	T	W. Grand Blvd.	33.3	29.0-41.0
4:30-5:00	T	Seward & Chicago	41.0	34.0-46.1
5:15-5:30	T	Seward & W. Grand Blvd.	37.5	34.0-41.0
5:30-5:40	T	W. Grand Blvd.	38.9	37.0-41.0
3:30-3:45	W	W. Grand Blvd.	41.2	40.0-42.3
4:00-4:15	W	Chicago & Seward	30.6	28.5-33.9
4:15-5:00	W	Webb, Chicago, & Seward	28.2	26.0-31.7
5:00-5:35	W	Chicago & Seward	36.6	31.7-50.5
3:45-4:00	Th.	Chicago & Seward	45.0	38.7-49.7
4:00-5:34	Th.	W. Grand Blvd.	44.7	37.0-52.2
3:30-3:56	F	W. Grand Blvd.	38.0	33.7-47.5
3:56-5:11	F	Chicago & W. Grand Blvd.	43.5	37.0-50.8
5:11-5:35	F	W. Grand Blvd.	42.0	36.6-46.8
			Average 38.5	

ALL RAMPS OPEN

Average Weekday Periods	Average Travel Time Speeds (Lanes 1 & 2) (MPH)
Northbound	
P. M.	
3:00-3:15	44.2
3:15-3:30	49.2
3:30-3:45	36.0
3:45-4:00	27.0
4:00-4:15	28.0
4:15-4:30	30.7
4:30-4:45	29.0
4:45-5:00	22.7
5:00-5:15	20.5
5:15-5:30	21.4
5:30-5:45	24.9
5:45-6:00	28.8
6:00-6:15	37.2
6:15-6:30	43.4
	Bracket Average 25.5

Southbound					Southbound	
A.M.					A.M.	
7:30-8:00	T	Glendale & Webb	35.4	32.3-42.7	7:00-7:15	39.1
8:15-8:30	T	Glendale	42.0	36.1-45.6	7:15-7:30	33.4
7:30-8:30	W	Glendale & Webb	37.0	31.3-43.1	7:30-7:45	24.4
7:35-7:50	Th	Davison	28.4	27.5-28.9	7:45-8:00	27.6
8:00-8:30	Th	Glendale & Webb	39.6	30.5-48.2	8:00-8:15	26.6
8:30-8:45	Th	Davison	40.7	39.5-42.7	8:15-8:30	28.3
7:15-7:50	F	Glendale	33.8	28.1-43.7	8:30-8:45	28.0
7:50-8:20	F	Glendale & Webb	37.2	34.3-39.5	8:45-9:00	22.9
8:20-8:40	F	Glendale	40.3	38.0-43.7	9:00-9:15	34.3
					9:15-9:30	40.1
			Average 37.2			Bracket Average 27.0

open to question, there can be no doubt that average travel speeds were significantly higher under most choices of ramp closures.

The afternoon period for northbound traffic produced similar results. Average speeds rose from 25.5 m.p.h., without ramp control to 38.5 m.p.h. with ramp control in effect.

The Chicago and Seward ramps were closed on Wednesday, March 6, from 4 p.m. to 5:35 p.m. The West Grand Boulevard ramp was closed during precisely the same hours on the following day. An x-y recorder was used to trace volume and speeds from the Chicago Boulevard sensors.

Graph 1 is a Wednesday tracing of volume and speeds with the Seward and Chicago ramps closed. This graph shows a range up to 40 vehicles per minute at over 30 miles per hour. A tracing made the following day, with only the West Grand Boulevard ramp closed, appears in Graph 2. It shows volumes as high as 45 vehicles per minute at speeds of over 40 miles per hour. This tracing substantiates other data obtained from this study that indicate that higher volumes and speeds can be maintained than had previously been believed possible.

This same speed differential shows also in Table IV. Average speeds on Wednesday from 4 p.m. to 5:35 p.m. vary from 30.6 to 36.6 miles per hour, compared to average speeds recorded on Thursday of 44.7 miles per hour.

Table V compares lane changing data for northbound traffic with (1) all ramps open, (2) the West Grand Boulevard ramp closed, and (3) the Seward Avenue ramp closed. The data shows a definite relationship between entering ramp traffic and lane changing.

TABLE V

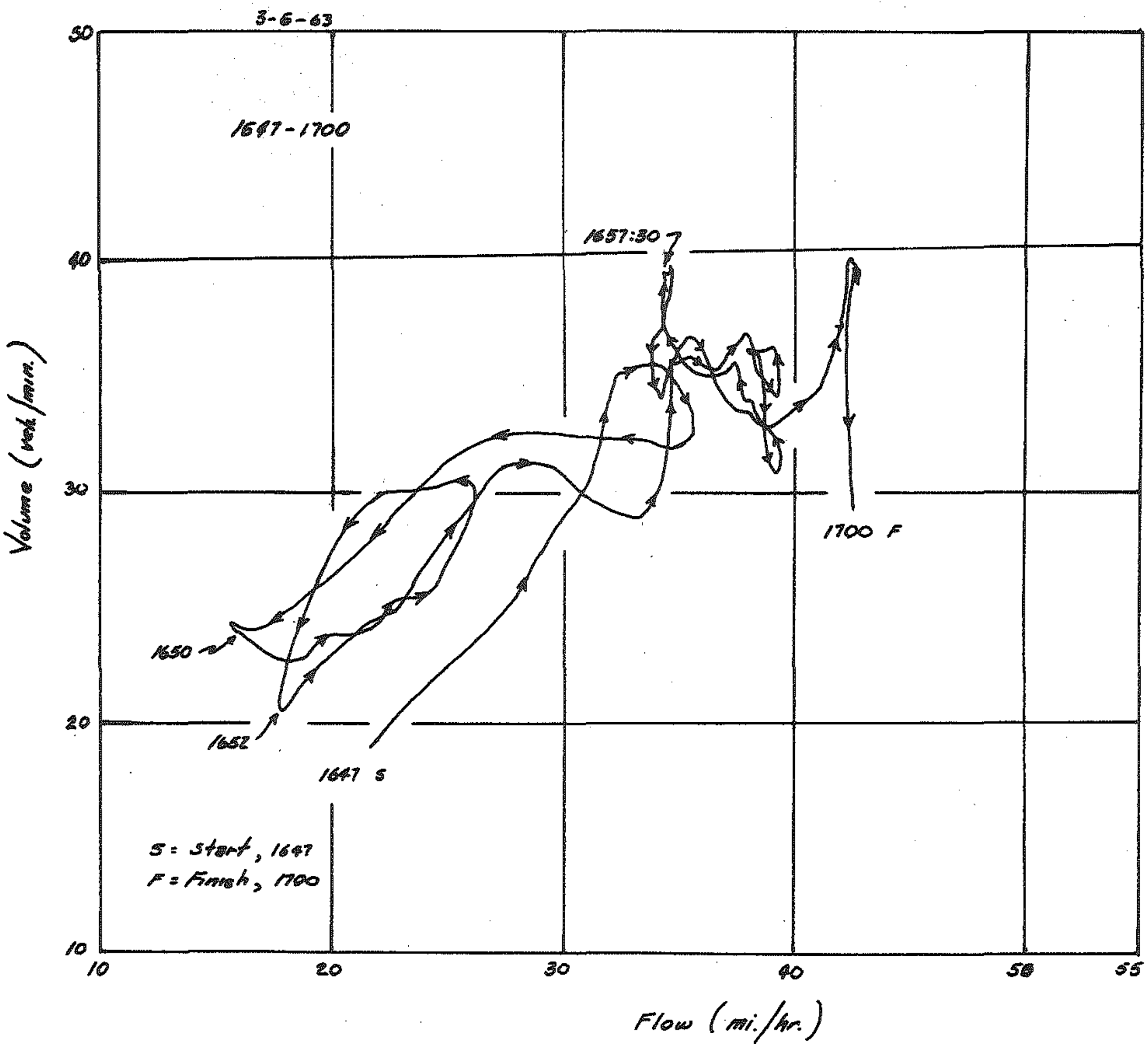
LANE CHANGE RATE COMPARISONS

Seward and West Grand Boulevard Ramps Closed vs. All Ramps Open

One Week Average (3:00 - 6:00 p.m.)

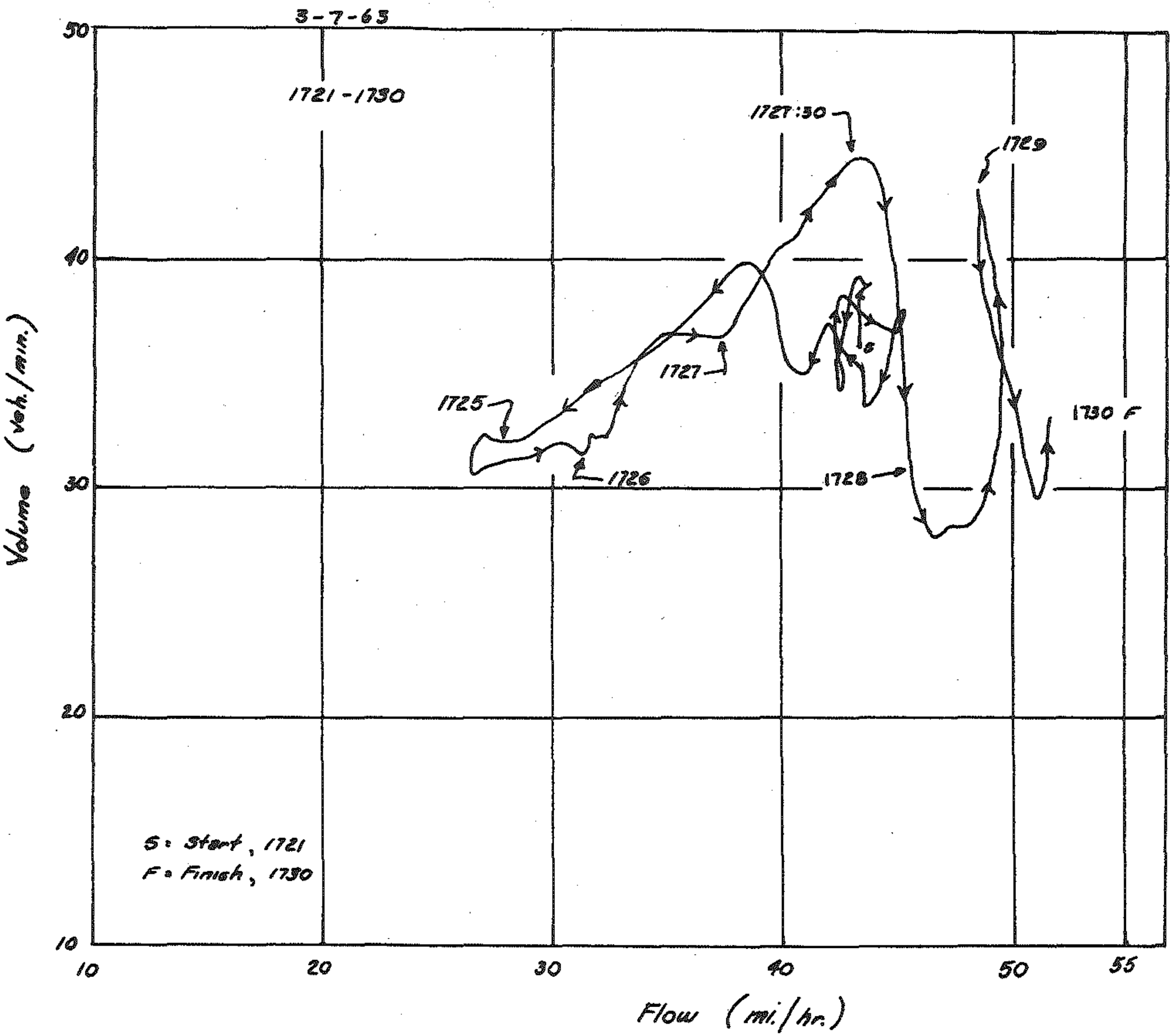
Northbound Direction Only

Condition	Camera Fields								
	Webb 3	Calvert 4	Chicago 5	Total	Gladstone 8	Euclid 9	Seward 10	Pallister 11	Total
All Ramps Open Lane Changes Per Minute	.4	.4	.15	.95	.7	1.6	1.7	2.9	6.9
W. Grand Boulevard Closed (Camera Field 12) Lane Changes Per Minute	.6	.8	.1	1.5	1.2	2.8	1.2	1.3	6.5
Seward Avenue Ramp Closed (Camera Field 10) Lane Changes Per Minute	.6	1.0	.4	2.0	.4	1.2	1.2	3.1	5.9



3-6-63
1647-1700
1657:30
1650
1652
1647 S
1700 F
S = Start, 1647
F = Finish, 1700
Volume (veh./min.)
Flow (mi./hr.)

Graph 1


3-7-63
1721-1730
1727:30
1729
1725
1726
1727
1728
1730 F
S
S: Start, 1721
F: Finish, 1730
Volume (veh./min.)
Flow (mi./hr.)
50
40
30
20
10
10
20
30
40
50
55

Graph 2

In studying the effects of ramp control on lane changing, not all camera fields were covered. This was due to limitations of personnel and the location of some cameras in areas of the freeway least likely to be influenced by ramp control.

Lane changes per minute, observed in the Webb (Camera 1), Calvert (#2) and Chicago (#3) camera fields, show that fewer changes occur in the north area than in the south portion covered by the Gladstone (#8), Euclid (#9), Seward (#10), and Pallister (#11) camera fields. A logical explanation is that in the north area only the low-volume Chicago and Webb ramps feed traffic to the freeway. The south portion receives traffic from the high-volume West Grand Boulevard ramp and the above -average Seward entrance ramp.

The lane change rate is high in Camera field 11 where heavy traffic enters from the West Grand Boulevard ramp. It is also high in Camera field 9, where the Seward ramp enters, when the West Grand Boulevard ramp is closed. Camera 7 to 11 cover the four-lane section.

Camera field 10 carries much the same rate of lane-changing regardless of ramp conditions (1.2, 1.2 and 1.7 changes per minute). Changes in this field are nearly equally divided between left and right. Further studies in this four-lane field may show that 1.2 lane changes per minute is an optimum rate, based on traffic desire for downstream exits and changes to median lanes for through movements.

The study results show significant differences in lane changing under the influence of ramp control. Final interpretation of results will require future study because of two factors which apparently work against each other. Ramp control produced more fluidity of traffic movement, which allows more lane changes than would be possible under conditions of congestion. But opposed to this is the reduction of entering traffic in certain areas under ramp control. This should diminish the number of lane changes that would otherwise occur.

The subject of lane changing will require much more detailed study. The findings of this study show definite merit to such investigation.

Table VI shows how lane changes to the left were affected by various ramp closures. The results show significant variations from one period of the study to another; but, again, proper analysis is difficult because of variables beyond the control of the experiment. The number of lane changes, in the camera fields studied, was generally higher with ramp closure. The percentage of lane changes to the left, as compared to the total number of changes, showed wide variations but no definite association with ramp closure.

With the Seward ramp closed, lane changes show consistently high percentages of movements to the left, ranging from 63 to 70 percent. With the West Grand Boulevard ramp closed, high percentages (85 to 93%) were measured in fields 8 and 9 where the Seward ramp traffic affects the freeway traffic.

The relatively low number of lane changes when no ramps were closed seems to indicate that under congested conditions changes are so difficult that few are attempted.

TABLE VI

DIRECTION OF LANE CHANGING COMPARISON

Northbound Direction Only

Condition and Time Periods

Camera Fields	Seward Closed Wednesday 4:00-5:35 pm			W. Grand Blvd. Closed Thursday 4:00-5:35 pm			W. Grand Blvd. Closed Friday 3:30-6:00 pm			No Ramps Closed Tuesday 4:15-4:30 pm			No Ramps Closed Wednesday 3:45-4:00 pm			No Ramps Closed Thursday 3:10-3:45 pm		
	Number of Lane Changes and Percent of Left Movements of Totals																	
	Total	Left	%	Total	Left	%	Total	Left	%	Total	Left	%	Total	Left	%	Total	Left	%
8	42	28	67	70	63	90	187	160	86	--	--	--	7	6	85	30	22	73
9	133	84	63	164	140	85	573	531	93	55	46	84	22	18	82	20	13	65
10	116	81	70	67	35	52	215	109	51	8	5	63	9	4	44	16	14	88
11	320	218	68	155	52	34	159	70	44	56	38	68	70	52	74	90	63	70

A future study should include the volumes of both entrance and exit ramps, along with freeway volumes in each study area, to obtain change rates. These would have to be compared to traffic stream velocities during the period of study.

In Table VII, a comparison of congestion periods, with and without ramp control, was made. These periods were declared to be ended when stoppages due to traffic congestion were no longer present.

Table VII compares the duration of congestion periods during the study week with those occurring during the three weeks before the study. Congestion periods were regarded as ended when stoppages caused by congestion were no longer present.

For northbound traffic, congestion periods were shortened by more than an hour in some instances. The average reduction in duration of northbound stoppages was 37 minutes.

For southbound traffic, congestion periods were shortened as much as 39 minutes; the average reduction was 16 minutes.

The difference between the north- and southbound reductions is accounted for by the fact that none of the southbound ramps carry volumes of entering traffic equal to the northbound Seward and West Grand Boulevard ramps.

The shortening of the congestion periods by ramp control appears consistent with other facts known about metropolitan traffic patterns. It is reasonable to assume that a fairly constant number of trips are generated

TABLE VII

CONGESTION PERIODS COMPARISONS *

CONGESTION PERIODS BY DAY

	Tuesday	Wednesday	Thursday	Friday	Average Ending Times
----------------	Northbound -- P.M.	Peak Period	----------------		
Previous	(3:42-5:45	3:39-6:05	3:39-5:57	3:47-6:06)	
3-Week	(3:47-5:41	3:38-5:57	3:28-5:45	----)	5:57
Period	(3:47-5:50	3:44-6:29	4:15-6:03	3:49-5:49)	
Study Week	3:41-5:00	3:49-5:33	3:42-5:00	3:36-5:51	5:20
----------------	Southbound -- A.M.	Peak Period	----------------		
Previous	(7:12-8:27	7:28-8:58	7:16-8:53	7:15-8:54)	
3-Week	(7:23-8:51	7:28-8:49	7:12-8:51	----)	8:46
Period	(----	7:09-8:45	7:08-8:45	7:25-8:23	
Study Week	7:14-8:36	7:08-8:19	7:15-8:46	7:14-8:22	8:30

* Period with stoppages.

from an area in a fixed period of time. If existing facilities are unable to handle this traffic, movement is retarded over both the surface streets and the freeway system. This slow speed storage of vehicles produces congestion which endures until the capacity of the streets again catches up with the demand. This study seems to indicate that ramp closures were able to increase freeway capacity and thus handle more quickly a fixed supply of vehicles, either entering or leaving the central business district.

Table VIII was compiled to show the effectiveness of ramp signals at the various entrance ramps after a two-month period in which no enforcement was applied. The violation figures represent the volumes of traffic using the ramps in defiance of the "Don't Enter" sign. The percentages were computed by comparing the number of violators with normal ramp volume. The results appear to confirm previous studies in this area and conclusively point out the need for either continuous enforcement or a positive barrier.

Surface Street Analysis

Figures 2-7 show normal traffic volumes at various entrance ramps and their distributions to other ramps or surface streets as determined by machine counts at various locations.

Figure 2 shows that 64% of diverted northbound West Grand Boulevard ramp traffic enters at Seward. The other distributions indicate that close to 30% of the rest of the volume proceeded east to Second Avenue or east of Davison. In any case, this body of traffic apparently travels no farther on

TABLE VIII

RAMP SIGN VIOLATIONS

(Two Months After Study Week)

Northbound Ramp Closures	Violation % of Normal Volume	Southbound Ramp Closures	Violation % of Normal Volume
Chicago	28	Glendale	42
Chicago	44	Glendale	36
W. Grand Boulevard	24	Glendale	23
W. Grand Boulevard	32	Webb	37
Seward	54	Chicago	30
Chicago	21	Clairmount	11
		Clairmount	23

ALTERNATE ROUTES USED WHEN NORTH BOUND WEST GRAND BLVD RAMP IS CLOSED

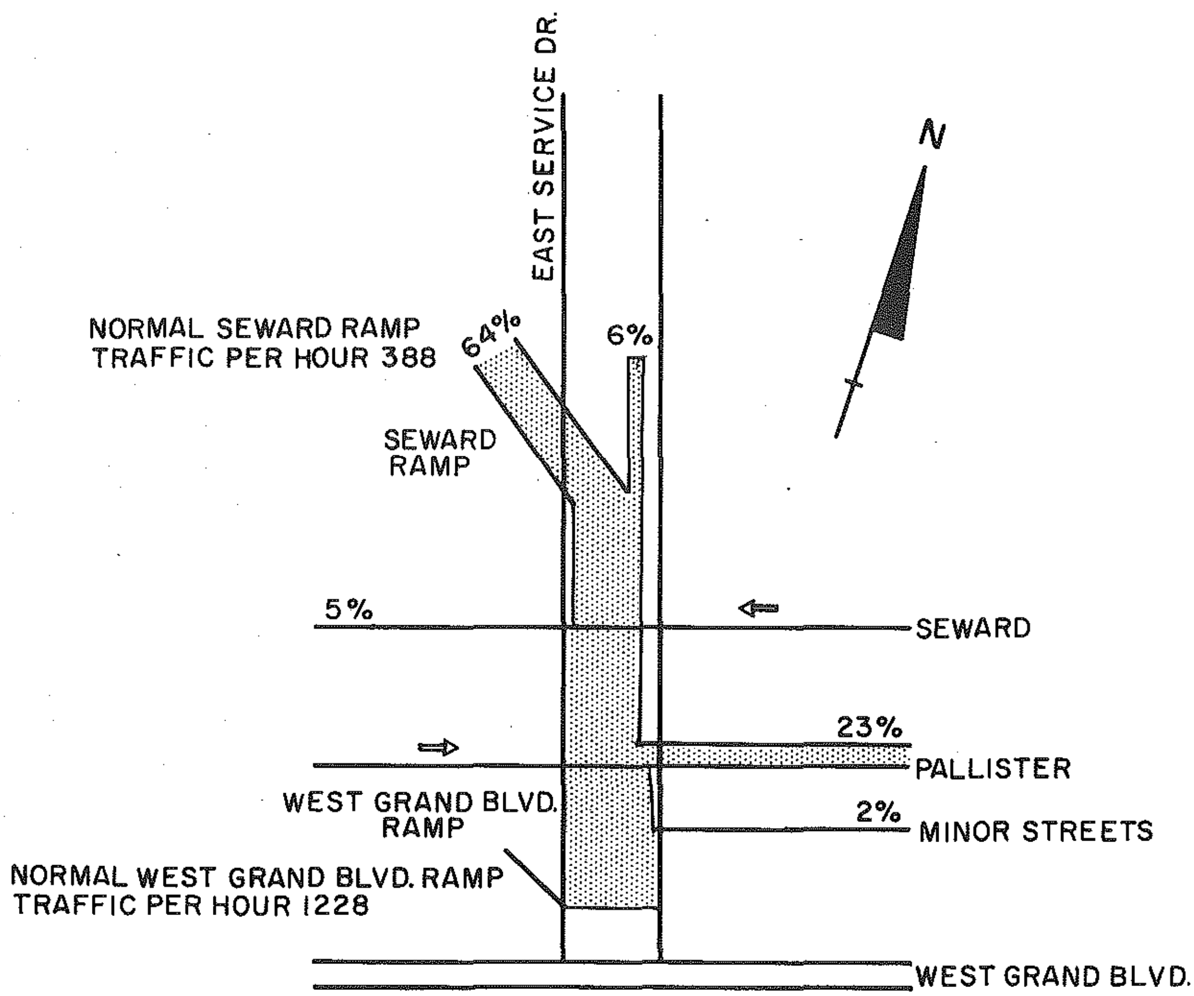


FIGURE 2

the Lodge Freeway than to the Davison ramps.

In Figure 3, Seward's dispersion pattern indicates a high percent of short-trip travelers inasmuch as all the diverted ramp traffic was dispersed before it reached Chicago Boulevard. Conversely, traffic diverted from the Chicago ramp appears to be freeway oriented. Sixty-seven percent of it entered the freeway at the Webb ramp, as shown in Figure 4.

For southbound traffic with Glendale closed, Figure 5 shows 37% of the normal Glendale ramp traffic entering at the Webb ramp, with most of the balance using surface streets. Sixty-nine percent of the Webb Avenue ramp traffic proceeds to the Chicago ramp. Most of the balance enters at Clairmount, as shown in Figure 6.

Figure 7 shows distributions resulting from combined Glendale and Webb ramp closures. Most of the diverted traffic proceeds to Chicago and Clairmount entrances. This traffic had little difficulty entering at these points since the fourth lane for southbound traffic begins at the Chicago ramp.

When closures were made at the eastbound Davison ramp, stoppages still occurred at Glendale (Camera 1). This was due to the westbound Davison ramp traffic that enters the freeway on the left and which includes a significant number of trucks.

Some of the short-period ramp-closure volumes could not be traced reliably, as at Milwaukee and Clairmount. Hence they are not included in the sketches.

ALTERNATE ROUTES USED WHEN NORTH BOUND SEWARD AVENUE RAMP IS CLOSED

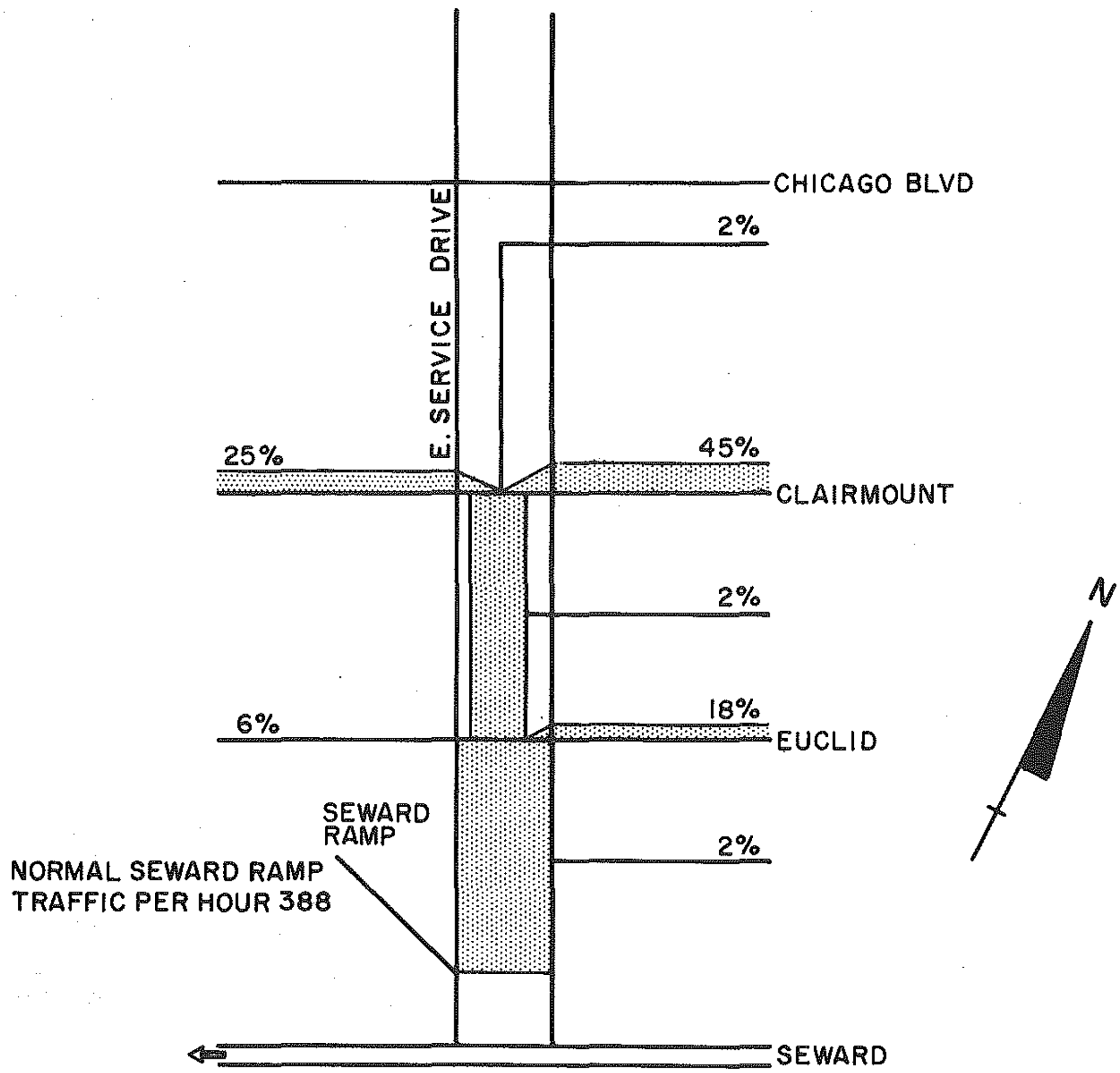


FIGURE 3

ALTERNATE ROUTE USED WHEN CHICAGO BOULEVARD NORTHBOUND RAMP IS CLOSED

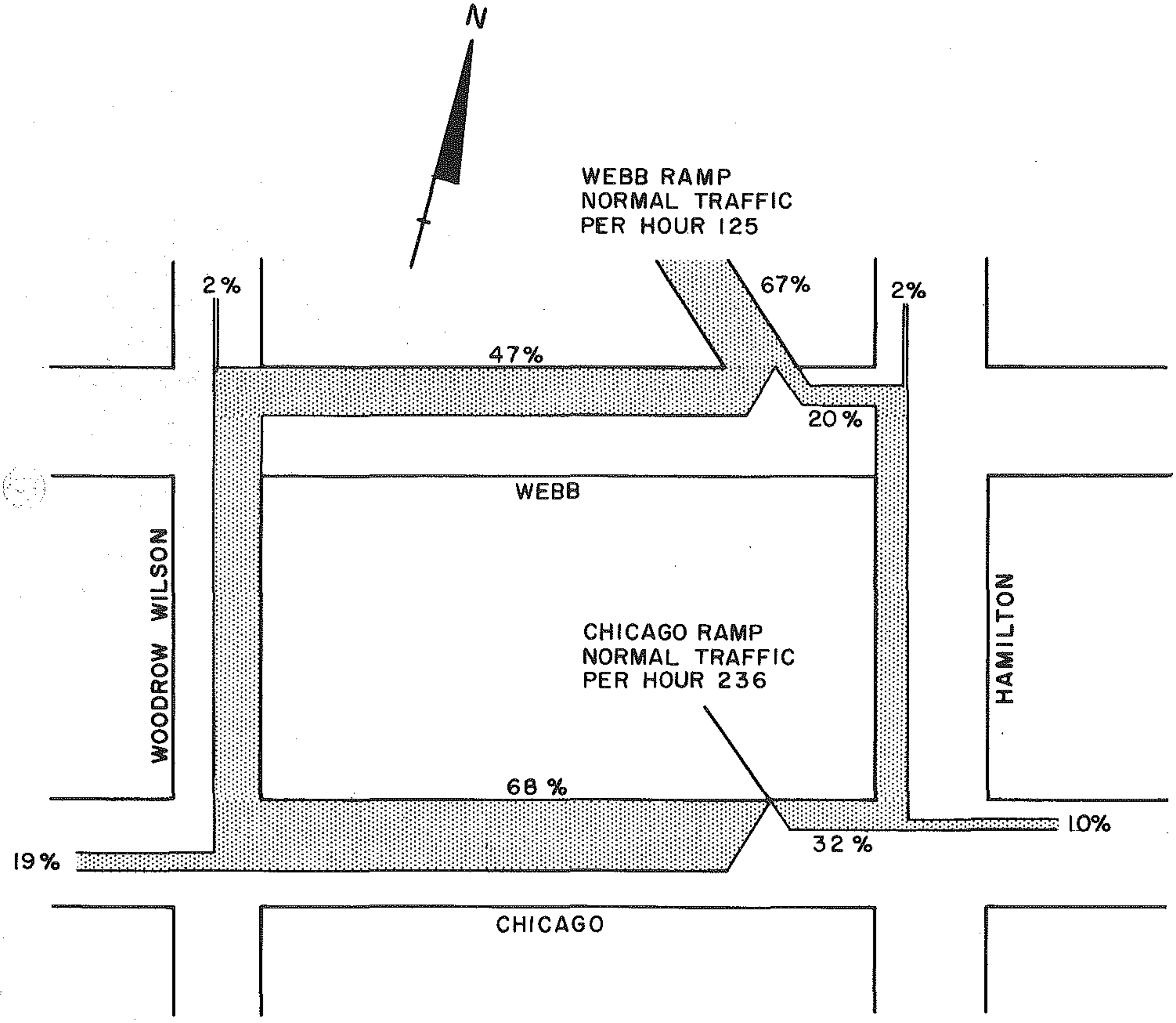


FIGURE 4

ALTERNATE ROUTE USED WHEN SOUTHBOUND GLENDALE RAMP IS CLOSED

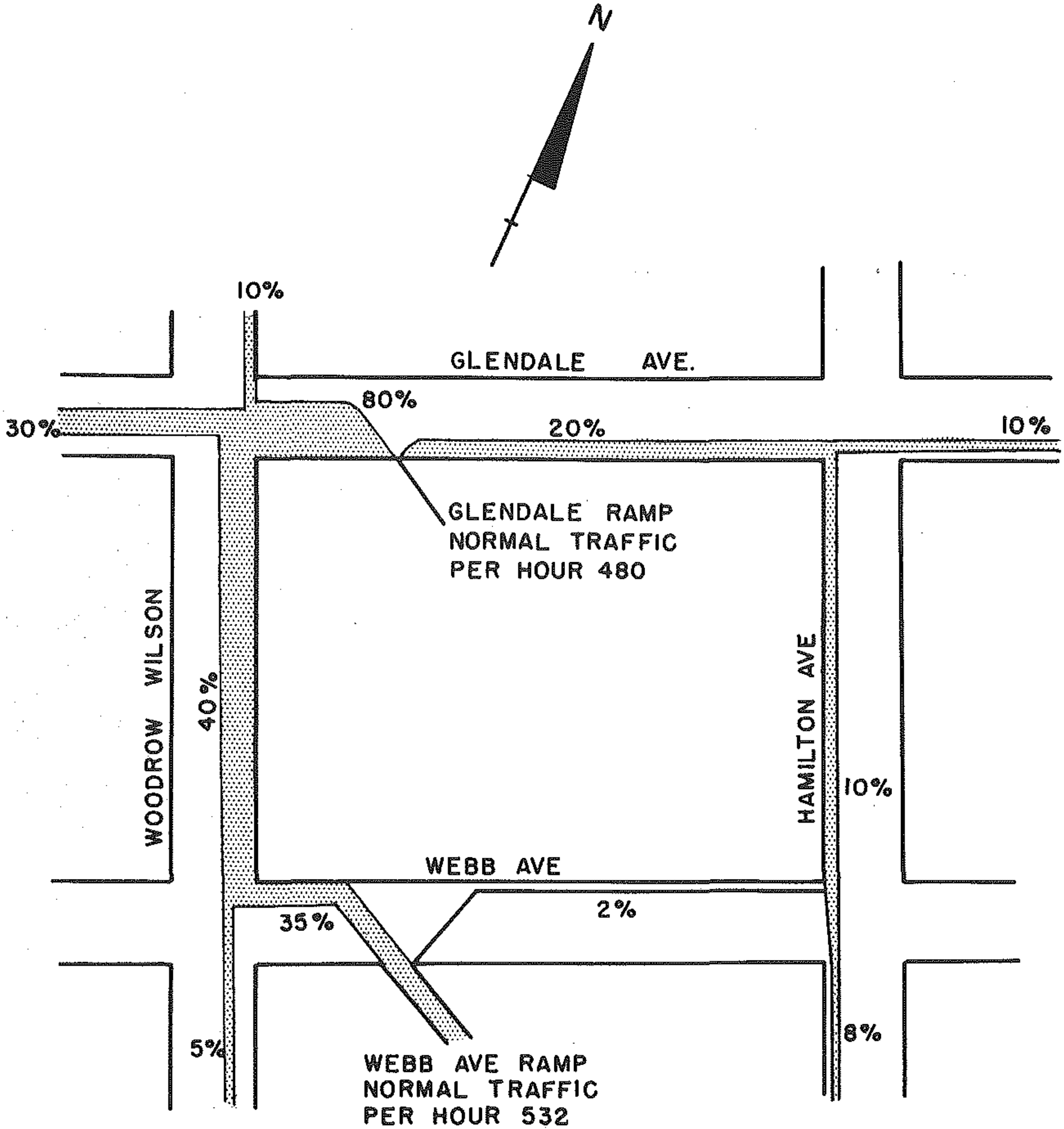


FIGURE 5

ALTERNATE ROUTES USED WHEN SOUTH BOUND WEBB AVENUE RAMP IS CLOSED

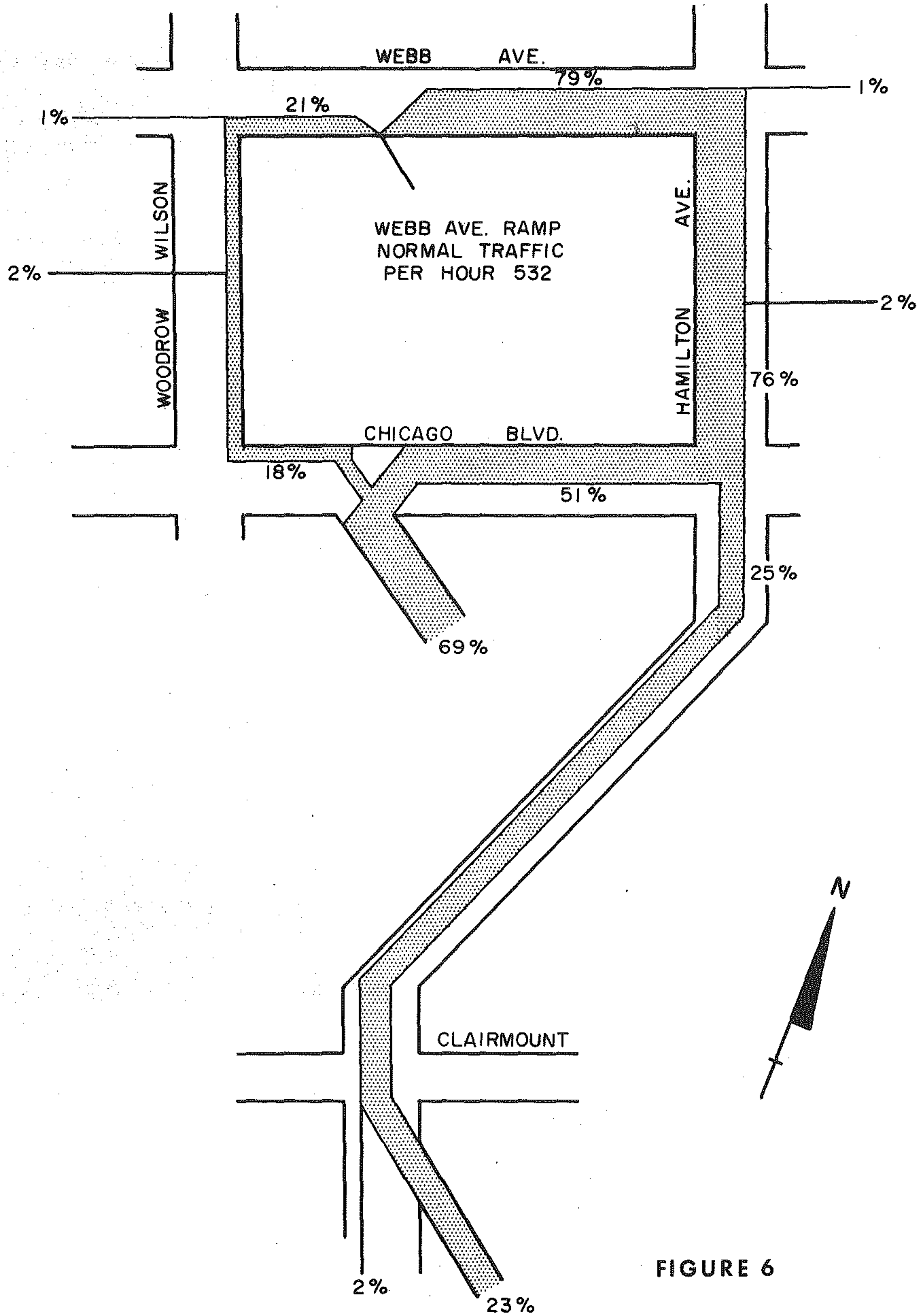


FIGURE 6

ALTERNATE ROUTES USED WHEN SOUTHBOUND GLENDALE AND WEBB AVENUE RAMP IS CLOSED

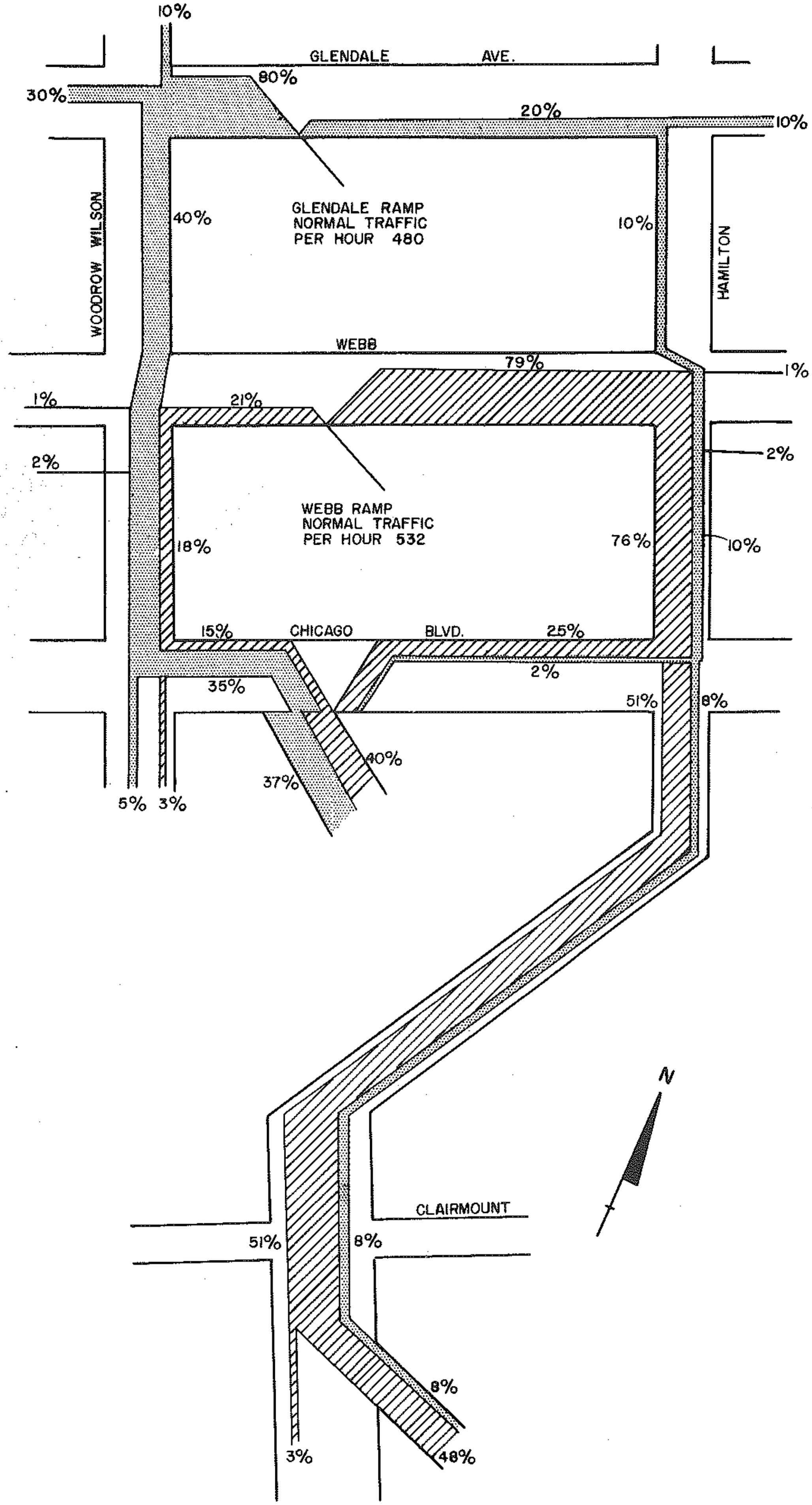


FIGURE 7

Diverted entrance ramp traffic for the three-hour outbound periods ranged from approximately 9 to 17% of freeway volumes. This diverted traffic merely had to proceed to the next available entrance ramp to continue in the desired direction. Or, in the case of short-trip drivers, surface streets served to allow them to complete their trips.

In the morning two-hour period, the closures diverted from 5 to 8.8% of the inbound freeway traffic. In other words, by shifting the entrance point for relatively few vehicles, it was possible to improve the movement throughout the whole study area. These diversions, for the most part, did not stagnate surface street movements. Surface street traffic usually moved steadily through the area between signal changes.

Summary

The one-week study shows that great gains in freedom of traffic flow are possible by using the ramp closure system, provided it is prudently adapted to conditions and that driver adherence to the "Don't Enter" signs remains high.

The ramp-closing experiment indicates that freeway traffic volumes were increased during the peak periods as much as 13.7%. Lane stoppages were reduced by to 92.5% in frequency for northbound peak traffic and up to 65% for southbound peak traffic. The stoppage waves that did occur traveled a much shorter distance upstream than those that occur without ramp control. Peak period stoppages averaged 77% and 58% less travel for each wave for north- and southbound traffic respectively.

These gains in traffic movement tend to prove the theory that much of the congestion on freeways and surface streets can be minimized by a traffic control system which keeps traffic moving at greater speed through or around areas of "bottlenecks".

Increases in peak-period traffic volumes are a result of higher average speeds on the freeway during ramp closing, along with reductions in the number and extent of lane stoppages. Examination of several ramp-closing incidents proves that even after the freeway reaches a condition of very low speed and stoppages, traffic capacity can be regained by closing ramps.

An example occurred during one afternoon peak period when a stalled vehicle affected all three lanes of traffic. Traffic in the three lanes (and in a fourth lane through part of the area) quickly came to a standstill. The stoppage extended for nearly two miles. By closing two ramps, Seward and West Grand Boulevard, after the stalled vehicle was removed, the accumulated traffic was cleared out and all traffic was moving in 22 minutes. Normally this sort of incident, which occurred shortly after 5 p.m., would have continued to produce congestion and slow-moving traffic until approximately 6:30 p.m.

Without ramp control, low capacity--caused by low speeds--will persist until there is a lessening of peak period traffic. The freeway is normally subjected to a series of "shock waves" traveling long distances upstream. With ramp control, the number of "shock waves" is greatly curtailed. The study demonstrates that ramp closure can dissolve these "shock waves" without affecting large areas of the freeway.

Observations on surface streets surrounding the freeway reveal many instances where improvement in traffic control would increase capacity. These changes could accommodate by-pass traffic from the freeway in a reasonable manner. While this statement must be confined to the situation in Detroit, it would probably be true elsewhere. Greater experience in ramp closure should make it possible to obtain needed increases in by-pass capacity by construction of facilities directly coordinated with a control system. This would be far more efficient than present methods in which surface street control is not integrated with freeway traffic.

To acquire information for future studies on use of the Lodge Freeway by traffic entering at West Grand Boulevard, a license plate study was conducted. A record was kept of the exits of this traffic at off-ramps beyond the West Grand Boulevard entrance as far north as the Davison interchange. This is a distance of about 2 1/2 miles. Of 3,043 vehicles recorded entering at West Grand Boulevard, 54 left at Clairmount, 198 at Hamilton, 51 at Glendale, and 282 at the Davison interchange. These figures show that 21.96% of traffic entering at West Grand Boulevard left the freeway within a distance of 2 1/2 miles.

Photo II shows a service drive filled with vehicles prevented from entering the freeway by a closed entrance ramp. One of the interesting observations made during the experiment was that numbers of motorists continued to use these by-pass routes after ramp control was discontinued.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Apparently the ramp closures taught them that surface streets offered more desirable travel paths during rush hours.

The study showed that closures of the Davison, Glendale and Webb ramps provided the greatest betterment for southbound freeway operation. The major restrictions for southbound traffic occurred in these areas with the Davison entrance ramp offering the most severe restriction. Traffic diverted from these ramps had little difficulty entering the freeway farther south at the Chicago and Clairmount ramps, due to the addition of another lane beginning at Chicago Boulevard.

Closing of the Clairmount and Milwaukee entrance ramps brought little or no improvement in freeway traffic behavior. This may seem unimportant, but it is actually quite significant. It supports the view that all ramps do not produce equal disruptions in freeway traffic, therefore, a careful selection of ramps to remain open avoids depriving widespread areas of the city of an entrance to the freeway. The public relations aspect of this point will be dealt with below.

Northbound traffic from the central business district regularly has stoppages in the area between the Edsel Ford Freeway (Camera 14) and Calvert (Camera 4). One hundred or more stoppages caused by congestion normally occur each day between 3:30 and 6 p.m. This condition is caused by left- and right-hand entrance ramps from the Edsel Ford Freeway joining the northbound Lodge Freeway. North of the Hamilton exit ramp, the Lodge

Freeway is reduced from four lanes to three without enough exiting traffic to justify the reduction. Even with these obvious deficiencies in capacity, ramp control was able to make definite improvements in freeway operation without any great sacrifice by motorists.

Trace recordings, made by an X-Y pen recorder, disclose many interesting relationships between speed and volume, with and without ramp control. While this recording method does not lend itself to the acquisition of composite data, it provided numerous examples in support of the fact that ramp control improves speed and capacity of the freeway.

The scope of this study and the limitations of present instrumentation do not permit conclusive evidence on the effects of ramp control. The results, however, are most encouraging and show definite benefits to be derived from future studies. Experiences gained from the initial study will prove invaluable in planning future work.

Conclusion

The results of the one-week experiment are being documented and will be publicized to acquaint Detroit's motorists with the advantages created by ramp closure. This will offset the complaints from neighborhood groups who believed that ramps were being closed for the convenience of people who live in the suburbs and to the detriment of city-dwellers. In one respect, this accusation is partly true since longer trips automatically receive the greatest benefits from ramp closure.

The public must be educated to the logic of ramp control and why it is needed to preserve good freeway operation. Benefits to the majority of motorists with a small sacrifice on the part of a few must be demonstrated. Motorists must be convinced that the by-pass routes offer a reasonable substitute to an otherwise congested freeway.

The situation is similar to removal of left turns from a street during rush hours to improve the capacity for through movements. If short-trip drivers are allowed to enter the freeway and add their traffic volumes to the saturated freeway traffic, total travel time may actually be longer for them as well as the people on the freeway. Once this point can be conveyed to the public, ramp closure experiments can be continued without difficulty.

On the whole, the public's acceptance of ramp closure has been good. The majority of motorists like the results. People who drove the freeway during the week of the experiment were quite lavish in their praise. A minority who were closed off from the ramp leading from their local area did voice objections. These are the people who must be convinced that the alternate surface routes are as desirable as the one they formerly traveled--and possibly a little better.

To improve this travel path, alternate routes will be established farther from the freeway so that areas of maximum congestion may be avoided. The use of animated signs is contemplated to give drivers information on conditions before they reach the freeway so that they may choose an alternate route, where such choices are available. Along the alternate routes, signals with changeable arrows under the trailblazer signs are proposed. This will avoid the directing of motorists to a ramp that has been closed. The arrow will always point out an alternate route to a ramp which remains open to freeway traffic. This arrangement could be made quite simply with the present control system.

Future experiments on ramp closure should also bring improvements in the TV surveillance system to provide better documentation of actual traffic conditions. The problem of getting more positive obedience to ramp signals can be alleviated by barrier gates along with the signals. Although financial considerations may prevent installation of a gate at each entrance ramp, certain ramps can be selected which will most effectively utilize the gates. The positive closing of these ramps in future experiments will provide more conclusive data which will either prove or disprove the benefits of ramp control.

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