

Lodge Freeway Traffic Surveillance And Control Project

Development and Evaluation

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This paper analyzes and evaluates the important characteristics and accessories of a closed-circuit television system for viewing urban freeway traffic and aiding in traffic control. The closed-circuit television system consisted of cameras, monitors, transmission equipment, and accessories. The paper also describes some typical research studies using the television system.

•THE John C. Lodge Freeway Traffic Surveillance and Control Research Project in cooperation with the U.S. Bureau of Public Roads is being conducted jointly by the Michigan State Highway Department, the City of Detroit Department of Streets and Traffic, and the Wayne County Road Commission. The project was initiated in July 1960. It is being conducted on the John C. Lodge Freeway between the Edsel Ford Freeway and the Davison Freeway. The study section is 3.2 mi long and includes portions of three- and four-lane freeway, as well as 9 off-ramps and 9 on-ramps (Fig. 1).

The project was programed over a 2-yr period and has provided an opportunity to conduct research on various aspects of driver and vehicle behavior on a heavily-traveled freeway. In addition, it has provided an excellent laboratory for the design, development, and evaluation of new and specialized electronic equipment for use in the study and control of freeway traffic characteristics. A great percentage of the effort and work on the project has been concentrated on designing and obtaining this instrumentation. During this period, equipment has been installed and its operating capabilities appraised; only in recent months has all the equipment been available for application to a concerted research effort.

The major objectives of the project are two. The first is to apply the latest developments in electronic and other related technological equipment to increase operational efficiency on the freeway. The equipment includes a closed-circuit television network and a traffic control system of lane signals, speed signals, and ramp closure signals. The second objective is to evaluate the effectiveness of this equipment in obtaining increased efficiency in freeway operation, as well as to conduct research on freeway traffic characteristics. The latter is directed toward the determination of interrelationships of traffic flow characteristics, new concepts on freeway traffic flow, and the study of driver behavior and its effect on freeway operation efficiency. For this purpose the General Railway Signal Company has loaned the project sensing and computer equipment for traffic data collection.

PROJECT INSTRUMENTATION

The instrumentation used is the latest and most sophisticated of its kind ever assembled for research activity as well as for traffic control. This affords an unequalled laboratory for research in freeway traffic study and control.

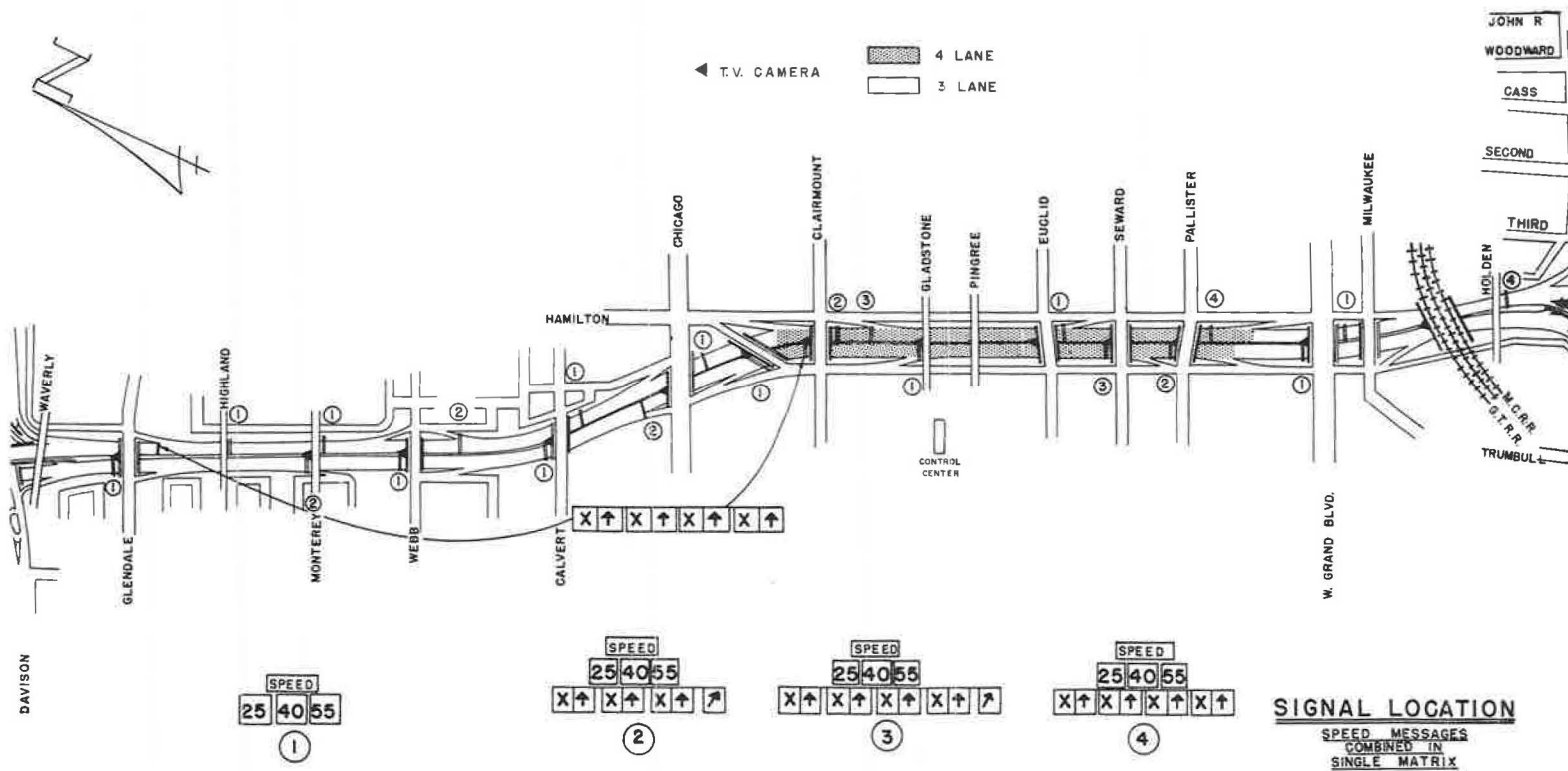


Figure 1. Signal and TV camera location, John C. Lodge Freeway, Detroit, Mich.

The instrumentation and equipment are grouped into three basic categories: television surveillance system, traffic control system, and traffic information collection equipment.

Television Surveillance System

On the project, there are 14 television cameras spaced approximately $\frac{1}{4}$ -mi apart, covering a continuous 3.2-mi area of the freeway (Fig. 1). This television system provided the principal type of surveillance. The television reception is transmitted to a control center located about midway in the study section. At the center, 14 monitors receive the video transmission from the cameras. Remote control is maintained here of all the available functions at all cameras, including changing a camera's normal lens to a telephoto lens, focusing, panning and tilting (that is, moving the camera right or left or up or down), and controlling the iris on each camera to regulate the amount of light received by the vidicon tube. In addition, the system provides for the automatic sequencing of the picture on the 14 monitors; with the spare monitor available, sequencing operation can be viewed independent of the 14 regular monitors.

Television surveillance has already revealed how very minor disturbances in the freeway traffic stream create congestion and may cause unsafe conditions. Surveillance and detection can be done in a matter of seconds. After 20 months of operation, there is no doubt that the system serves very efficiently for detection and, subsequently, has aided greatly in the traffic control corrective measures that have been made. The visual observation of the traffic stream and, in particular, traffic situations such as accidents, congestion, and vehicle breakdowns, has been of tremendous help in aiding the operator to detect the situation, determine its scope and extent, make the necessary corrective action, and immediately evaluate the result of this corrective action.

Experience so far has led to the conclusion that it would be extremely difficult to operate an efficient traffic control system without the type of viewing provided here.

Traffic Control System

Lane Control Signals.—The traffic control system consists of lane signals and variable speed signs on the freeway, and ramp closure signs for control of the on-ramps. Lane signals and variable speed signs were installed during the early months of 1962, and operation of them began on May 7, following a 30-day shakedown period for operating errors. The lane signals use the red X and green arrows which are the new national standards for signals of this type (Fig. 1). The red X means the driver must leave the lane, as soon as it is safe to do so, and move over to a lane displaying a green arrow, either a through lane or an exit ramp lane at the location where the signal span is installed. The green arrow indicates that the lane is open to traffic but does not mean that the driver has a route guaranteeing absence of traffic stoppages. The red X is not employed unless the lane is closed for maintenance or an emergency. The lane control signals are installed at 11 locations in the study section—6 for the northbound and 5 for the southbound direction.

Variable Speed Control.—A variable speed sign is used in conjunction with the lane signals. It displays messages in 5-mph increments over a range of 20 to 60 mph. Speeds are determined through the sensing equipment from information that has been automatically analyzed by computers in the control center. Signs have been installed at 21 locations; in some instances, with a lane signal span, and in others, by itself. There are 11 for the northbound and 10 for the southbound direction.

Ramp Control.—In addition to the lane signals and variable speed signs, ramp signals are being installed on each on-ramp in the study section. There are 9 such locations—4 northbound and 5 southbound. These signals enable the operator to close a ramp if congestion or an incident has occurred on the freeway near an on-ramp, diverting traffic along an alternate route until it can conveniently enter the freeway. The ramp signal's legend is "Don't Enter." It is a blank-out sign with a legend plate with the word "Ramp" attached to the bottom. The control center operator is able to close ramps when necessary and provide better control of entering traffic, thereby increasing not only the efficiency of the control system but also the capacity and operation of the

freeway. There has been no opportunity to evaluate these signals individually or the control system with these signals in operation.

Supervisory Control.—The nature of the freeway lane signals, variable speed signs, and ramp control requires a remote control facility. The supervisory control equipment, located at the TV control center, is operated by personnel observing the freeway traffic. A console contains the controls to activate any signal or speed sign. On detection of an incident on the freeway the control operator selects the function needed to alleviate whatever situation has occurred.

The operator is provided with a confirmation panel which shows on a schematic of the study section the location of the signals and signs. The confirmation panel through the supervisory control circuitry informs the operator that the function selected has been properly sent and confirms that the message has been received and is not in error. Because of the critical nature of any action that causes a change in traffic flow, it is obvious that the control system must possess a means of positive confirmation. This control system circuitry will automatically tell an operator immediately whether there is any malfunction in the system. This equipment permits the selection of complex functions which can be carried out with complete reliability because of the fail-safe features.

Future Equipment Requirements.—An evaluation during recent months of operation has revealed that certain additions and revisions are necessary if the complete potential of the control system is to be realized. The system cannot provide optimum control of freeway traffic unless these changes are incorporated as part of the total system. As this system was the pioneer project of its kind, it is natural that changes would follow the initial operational period. The following are the proposed changes and additions which will satisfy the requirements for properly controlling traffic in the study section:

1. Additional Lane Signals and Speed Signs. When the system was first designed, the present installation of lane signals and speed signs was determined to be the absolute minimum. Project personnel felt that additional signals and signs might have to be installed, but due to financial limitations and the desire to keep costs at a minimum, the present equipment was approved.

However, shortly after beginning operation, it was determined that the distance between adjacent signal spans in two locations was too long for efficient control of traffic. Therefore, two additional spans of lane signals and speed signs are required at Chicago Boulevard for northbound traffic and Webb for southbound.

2. Individual Speed Sign Control. The present system of speed control was designed to gang or zone the speed signals in twos and threes. That is, in some instances one control activates more than one signal simultaneously. Early experience indicated that it would often be desirable to regulate traffic by speed and that a different speed should be displayed at adjacent signals. Therefore, to provide greater flexibility, thus increasing efficiency, it was decided that they should be individually controlled. This will be done as soon as possible.

3. Speed and Presence Detection Equipment and Display. To operate the control system effectively, complete information on speed, occupancy, and volume at many locations must be available. Presently, the only available traffic data that assist in detecting any change in traffic flow and indicate that congestion is eminent are provided from two locations where speed, occupancy, and volume sensors are placed over each lane in both directions. However, such information from these locations may not apply to other areas in the study section limiting the effectiveness of the control.

It is thus proposed that speed and presence detectors be placed equidistantly along the study section to provide the operator with complete information on traffic flow at many points, thereby increasing his knowledge of the existing character of traffic flow and providing greater assistance for judging what control action is required.

Traffic Information Collection Instrumentation

The project has available a laboratory of electronic instrumentation, the latest of its kind, which provides the means of obtaining traffic information. Ultrasonic sensors are used for vehicle detection, the impulses being transmitted to analog computers

located at the control center. Here, the information can be read directly from meters or plotted on an eight-pen recorder for later tabulation and analysis. The equipment is capable of providing lane speeds, lane occupancy, lane minute volumes, freeway occupancy, freeway volumes, and freeway average speeds. In addition, it can provide total vehicle counts and distinguish between passenger and commercial vehicles.

The capabilities of this instrumentation are unsurpassed anywhere in the United States, yet it is provided without cost to the project. To purchase all this equipment would cost about \$150,000. The capability of the system dictates that the fullest advantage be taken of this opportunity to study freeway traffic characteristics. The large quantity of traffic information requires the application of computers to its analysis and handling.

PROJECT RESEARCH ACTIVITIES

Television Surveillance for Freeway Traffic Observation and Research

The television system provides an excellent opportunity to conduct research into freeway traffic, as well as to employ television surveillance for traffic control. It also has provided the opportunity for extensive use as a research tool in the observation, assimilation, and collection of research information. The system can instantaneously transfer information to an observer who can view a large area of the freeway, follow traffic, and examine details by remote control functions. The unique nature of the application of closed-circuit television to freeway surveillance requires that a complete evaluation be performed on all aspects and features of the television system in anticipation that the system will become a permanent installation for each standard or that similar installations will be undertaken elsewhere.

Technical Evaluation.—A comprehensive evaluation has been conducted to provide an objective appraisal of the technological features of the television system. It covers the location of cameras and accessories, transmission line and facilities, and monitor presentation and orientation. It also includes a comparison of the existing features with alternates of the latest technological design and recommends changes and applications consistent with these developments. The final report on this evaluation has been completed and is being prepared for publication.

Television Information for Research.—Television surveillance to supply research information reveals its qualification as a research tool. However, the determination of the extent and character of the information available and the accuracy with which this information can be obtained must be performed. The nature of the television surveillance phase of the project requires maximum use of this medium by continuous monitoring of the freeway.

This leads to further research to determine the qualifications and limitations of the personnel who are engaged in monitoring freeway traffic. It is necessary to determine the observers' abilities and limitations to establish the level of reliability of the information obtained.

It is also important that this research be performed for the benefit of other agencies should they desire similar installations throughout the country. In addition, it is necessary to research available methods for recording information that is visually obtainable from the monitors. This, of course, involves much experimentation and use of present facilities, such as photographic equipment and, possibly, video taping.

The following studies are under way for this purpose:

1. The scope and limitations of freeway traffic information available through television.
2. Determination of the accuracy of this information.
3. Methods of recording this visual information.
4. Determination of television observers' abilities and limitations.
5. Investigation of the uses of simultaneous viewing and/or sequential viewing.

Television Surveillance Research Application

Television surveillance has been used extensively to obtain research data for many

studies. Considerable discussion has already been presented on the research potential of this system. The following discusses the studies involving television observations in the performance of research.

Shoulder Usage on an Urban Freeway.—Research of shoulder usage was the first study in the project in which television provided the primary means of obtaining data. Its general objective was to determine the extent and characteristics of shoulder usage on an urban freeway. The particular objectives were to study the following:

1. Amount of shoulder usage on some rate basis such as vehicle-miles per mile or per hour.
2. Use by type of vehicle.
3. Length of stay.
4. Reason for using the shoulder.
5. Assistance received.
6. Other vehicles involved in a given incident.
7. Relation of findings to other shoulder usage studies.

Trained observers watching the monitors obtained data excluding volume information. When a shoulder usage was observed, the time and location were also recorded using the camera field and direction of travel as reference points. The reason for the stop was determined entirely from the observer's evaluation of the incident. If there was no obvious reason for stopping, the cause was listed as undetermined. No attempt was made to determine the actual reason for stopping because a part of the study was to determine the length of the stay under normal conditions. Traffic data were collected from automatic vehicle detectors and recorded at specified times to determine the vehicle-mile information.

The field studies were conducted in May and August 1961. No attempt was made to determine the number of incidents that was missed by the observers and accuracy is assumed, subject to the completion of an observer evaluation study. It is known, however, that incidents were missed, so that the results are on the conservative side.

Shoulder usage has never been studied as fully as on this project. The work could not have been performed without the television system. The results have already produced benefits inasmuch as the data were used in deciding to include refuge shoulders on the high-level bridge over the Rouge River in Detroit. They have also been used as a basis for a parallel study on the Illinois Surveillance Project in Chicago. However, the Chicago study does not have television surveillance.

Lane Change on an Urban Freeway.—The purpose of the study was to determine and analyze by section vehicle lane changes, which were observed in 13 of 14 camera fields from the monitors. All lane changes by type of vehicles were observed in each field by observers during weekdays for an off-peak hour and a peak hour. Morning peak hours were observed in the southbound direction, and afternoon peak hours in the northbound. Volumes of traffic by type of vehicle were also obtained from the monitors and recorded manually for each camera field on a comparable weekday for the same 1-hr periods.

Inasmuch as the length of roadway required for lane change depended on several factors, lane change movements were recorded in the field in which they were started. The length and end location of the change were not considered. Television provided an excellent means of obtaining extensive data which may particularly assist in the determination of relationships between lane changing and geometric features. Additional research is contemplated on the effects of the control system on lane changes.

The data from this study have found immediate use. They have been applied by Cook County, Ill., traffic officials in the special problems of design and location of freeways and freeway ramps.

Measuring Travel Time by Television Surveillance.—One of the first research studies performed was the determination of the ability to measure travel time from television surveillance. It was considered that, if the travel time of any vehicle could readily and accurately be so obtained, movement of vehicles or groups of vehicles through surveillance area could be surveyed relative to speed, delays, stoppages, and lanes traveled, and classified by types of vehicles. The study was conducted for a

5-day period in April 1961 by using several observers at the control center who timed two test vehicles on the freeway, passing through television camera fields.

The primary objective on the first day of the study was observation of the test vehicles to determine the accuracy in timing vehicles from a monitor. While the test vehicles were on their return trip in the unmonitored direction, random vehicles were selected and timed through the study area.

On the other four days, the test vehicles were not timed; only randomly selected vehicles were observed and timed. The test vehicles, however, continued their runs each day during the study periods, and recorders in the vehicles recorded the time of passing predetermined reference points.

Three different travel time study techniques were employed in the test vehicle runs: the following car method and the floating car method (both throughout the week); and (on the last day) some maximum car runs. Vehicle type, weather, direction, pavement condition, and date were also recorded. Standard passenger cars were the major sampling, with minor coverages of other vehicle types. Vehicles were chosen starting in various lanes. Some observers became proficient to the point that they could individually observe the progress of the vehicle past each location marking and also record the time to the nearest second on the control room clock. For other observers it was necessary to have a recorder working with them to log the times on data sheets. During the study hours, recordings were taken each minute of the volume, density, and flow speed in each lane from the Chicago Boulevard detectors.

Comparisons made between the travel time as recorded by the test vehicles and that



Figure 2. Median lane closure, Gladstone, before phase.

obtained from the monitors confirmed the reliability of securing travel times of vehicles by television. The results showed great similarity between monitor-observed timing and the timings of the test vehicles. In fact, 3 sec was the greatest variation for all runs under 6 min.

In addition, the travel time results were used as a means of evaluating the traffic control system. Other information useful to other studies was also obtained—including lane changing. Also, statistical methods and computer application will be used to determine the possibility of sampling travel time to obtain representative values. Further study is to be conducted.

Time Savings in Detection of Incidents.—Another aspect is the aid television provides in the detection, evaluation, and the dissemination of information on freeway incidents, such as accidents and vehicle breakdowns. A study now in progress has the specific objective of determining the time savings derived from television surveillance whenever such incidents occur. This benefit can be translated into convenience, efficiency, and safety. Before installation of the television system, notification of any incident was either by an interested motorist in calling the police or by the police on routine patrols. Police records have supplied information on the time involved in the notification and the arrival of assistance vehicles to the scene.

With television surveillance it is possible to detect the incident readily and notify police or emergency vehicles. Time savings will thus accrue for the vehicle involved in the incident and for the total freeway traffic, because assistance vehicles will arrive sooner and the disabled vehicle will be moved to the shoulder sooner, thus reducing traffic delay.



Figure 3. Median lane closure, Gladstone, after phase.

The television observer directs the proper assistance vehicles into the area and the information concerning the actual location is of assistance to the police. The control center is equipped with a direct phone line to the police department radio dispatcher.

In this study benefits accrued from the television in the way of time savings to the motorist and the disabled vehicles and to the total freeway traffic can be easily measured. Final results will be available in the near future.

Effects of Constricted Flow on Freeway Traffic.—Constricted flow is a situation in which one lane or more is blocked or partially blocked, reducing the number of traffic lanes. This constriction is created by various situations, such as an accident, a disabled vehicle, or maintenance crews working. The objective of this study is to determine the effects of lane constriction on traffic volumes and lane capacity. Data were obtained before operation of the freeway signal system in order to measure the effect and benefits of the system in such traffic situations.

In cases where maintenance crews closed a portion of one lane, the method and time of closing were taken into account, as these two factors reduce the normal volumes of traffic at the location of the constriction. From television surveillance, on-the-spot observations can be made whenever such constrictions occur, and the method of closing lanes, their location, and the equipment being employed by the crews can all be studied to determine effects on normal operation. From this study, it may be possible to initiate procedures for closing a lane for maintenance operations in order to achieve better efficiency and lessen the reduction in traffic flow.

In the normal or conventional methods of lane closure, warning is provided by



Figure 4. Middle lane closure, Gladstone, before phase.

advance signing plus a flasher trailer and barricades. With the use of the advance signing, it is anticipated that flow of traffic out of the closed lane will be more immediate because warning can be provided far in advance of the particular location. A constricted flow situation could not be planned or scheduled for this study, and data are to be collected whenever a situation occurs.

The before information has been completed. The after information from use of the control system and lane signals has also been completed, and comparison of these data will offer a measure of the effectiveness of a lane signal system. When constricted conditions occur, speed information is obtained wherever possible as are volume counts into, through, and beyond the constriction, and classification of vehicles. To correlate these data taken during constricted flow conditions with normal flow, sample volume counts are taken at the same location at approximately the same time on a day when no constriction is present. Preliminary data on this study have been prepared, and the use of this information will point out any benefit of lane control signals.

Preliminary results show that the average lane volumes in vehicles per minute passing a constriction have been consistently higher (20%) with the use of the control system lane signals. Speeds of vehicles and average lane speeds passing the constriction have also been consistently higher (by 50 to 60%). This improvement is, of course, due to the advance warning lane signals which allow vehicles to move under free-flowing conditions into an open lane.

Evaluation of Traffic Control System

A major area of research has been directed toward the evaluation of the traffic



Figure 5. Middle lane closure, Gladstone, after phase.

control system. This system consists of lane signals, speed signs, and ramp closure signals. It merits special research effort because it is the first and only control system applied to freeway traffic. Freeway control is a problem that exists in many urban areas where design capacities have already been surpassed to the extent that congestion is a daily occurrence.

Since May 7, 1962, when the control system was put in operation, research has been conducted to evaluate any benefit derived from improved freeway operation. Preliminary results indicate that improvement in freeway operation, and thus freeway capacity, can be expected from its use. The effect extends beyond the limits of the study sections; its influence can be noted in the areas immediately adjacent.

The results of the research were obtained from specific studies directed toward the investigation of certain phases of the control system: lane closures, constricted flow situations, and travel time.

Lane Closures. —Before installation of the control system, lane closures were introduced in the traffic stream by the use of a maintenance vehicle. Traffic information was obtained for comparison with like situations after installation of the control system. Observations were made from the control center, and the traffic information recorded included volumes, speeds, lengths of back-ups and delays at the closure, the number of vehicles in the closed lane, the number of lane changes, and the distance from the closure at which the lane changes were initiated. Sufficient information was also gathered to determine reduction in delays and erratic driving to measure the effectiveness of the system. In addition, motion pictures taken of the lane closure areas from a high



Figure 6. Stalled vehicle in median lane with characteristic traffic congestion.

vantage point provided visual records of the conventional method of closure as well as closure by the lane control signals.

The purpose of this study was to measure the comparative effectiveness of moving volumes of urban traffic past a lane closure using such conventional methods as flasher trailer cones, road signs, and barricades as opposed to the lane signal system. Lane closures were established for both directions of travel downstream from the sensing equipment at the Calvert and Chicago locations so that approaching volumes and speeds were recorded in three- and four-lane sections.

The before and after phases were conducted at identical locations to obtain similar conditions. The before phase was conducted in April 1962, and the after phase in July 1962. The after portion will be repeated when the ramp closure signals are installed.

The information obtained at the lane closures is as follows:

1. Time, deviation, and location of closure.
2. Average approach volumes in vehicles per minute (vpm).
3. Average speeds of vehicles in open lanes past closure.
4. Average travel speeds in camera areas upstream and downstream of closure from travel times.
5. Lane changing in areas adjacent to closure upstream in average vehicles per minute.
6. Vehicles per minute stopped in closed lane.

The closures were made at Gladstone in the southbound and at Webb in the northbound roadway. The Gladstone closure is in a four-lane section; the Webb closure, in a three-lane section.

Figure 2 shows the lane closure (median lane) for the before phase at Gladstone. Figure 3 shows the same closure at the same time of day after the signals were in operation.

Figures 4 and 5 show a closure in the middle lane for the before and after periods, respectively. Figure 6 shows a stalled vehicle in the median lane and the characteristic

TABLE 1
LANE CLOSURE COMPARISONS

Signals Installed	Approach Volume		Vehicles Stopped in Closed Lane (vpm)		Speed by Closure (mph)	Lane Change Location	
	Vpm	Vpm/ Lane				Distance from Closure (ft)	Percent of Changes
			Range	Avg.			
(a) Gladstone Southbound Traffic, 4-Lane Section, 3 Closures ¹							
Before	64	21	5-23	11	31	0-400	93
						1,000-1,500	7
After ²	68	22	0-2	1	51	600-1,000	31
						1,000-1,500	69
(b) Webb Northbound Traffic, 3-Lane Section, 2 Closures ¹							
Before	61	30	2.3-4.3	3.3	30	0-250	92
						350-1,500	8
After ²	80	40	0.8-2.2	1.5	31	200-900	37
						900-1,500	63

¹ One lane closed each closure.

² Advance lane signal 900 ft before closure.

congestion of traffic. No signals are in operation and no warning is provided the approaching traffic.

The preliminary results from the lane closure comparisons are given in Table 1. A definite trend is apparent which reveals increased freeway operation from the use of the lane signals during periods of lane closure. From the table, the following trends can be pointed out:

1. Lane changing from the closed to an open lane was initiated by motorists in some instances farther in advance of the closure with signals than without. At Gladstone, for the before condition, 93 percent of the lane changes took place within 400 ft of the closure by the conventional methods, whereas 69 percent of the lane changes during the after phase took place between 1,000 and 1,500 ft in advance of the closure. The 7 percent of lane changes in the before phase was indicated from the lane change study as being normal for the areas studied. The majority of the 31 percent lane changes in the after phase that began between 600 to 1,000 ft occurred in the distance from 700 to 1,000 ft. The advance warning permitted motorists to size up the situation ahead, adjust their position, and move into the open lane in sufficient time not to be trapped immediately at the closure.

2. The Gladstone closure indicated a slight increase in volumes approaching the closure (64 to 68 vpm); however, an increase in speed of vehicles past the closure ranged from 40 to as high as 60 percent.

3. At Gladstone, the range of vehicles stopped or trapped by closure was considerably reduced when the lane signals were in operation from 11 to 1 per minute of duration of closure.

4. At the Webb closure, the approach volume was considerably increased at the time of the after closure over the before as indicated by the approach volumes of 61 to 60 vpm. At the same time, the speed past the closure was approximately the same.

5. The lane change at the Webb closure indicated that the point of initiation of the lane change moved back with the lane signals in operation. This change resulted under the heavier volume conditions—92 percent began between 0 and 330 ft in advance of closure without signals, but 63 percent of the lane changes began between 900 and 1,500 ft with the signals in operation.

6. At Webb, there was also a reduction in the number of vehicles stopped or trapped immediately at the closure when the signals were in operation.

The handling of lane closures when the signals were in operation was a considerable

TABLE 2
CONSTRICTED FLOW COMPARISONS

Section	Signals Installed	Average Capacity	
		Lane (vph/lane)	Hourly ¹ (vpm/lane)
3-Lane	Before	25.70	1,542
	After	35.75	2,142
	Increase	10.05	603
	% Increase	39.1	
4-Lane	Before	22.2	1,333
	After	29.4	1,764
	Increase	7.2	432
	% Increase	32.4	

¹ Expanded.

improvement over that during use of conventional methods. These, of course, are preliminary results, but they do indicate a trend toward improved operation with the control system.

Evaluation of the other elements of the control system (the speed signs and the ramp closure signs) has not been completed. The evaluation of the speed signs is under way. The ramp signals are to be installed soon, and evaluation of the control system following their installation will be completed.

Constricted Flow Situations.—The results of the constricted flow study were derived from closures caused by maintenance vehicles, stalled vehicles, or accidents. As these incidents could not be scheduled, only a limited amount of traffic information was obtained because of manpower limitations at those times. The incidents occurred in both three- and four-lane sections of the freeway, and all data were collected from television surveillance. Results from incidents created by maintenance before and after the operation of the lane signals permit comparison with those from the scheduled lane closures.

During the incidents constricting flow, lane volumes passing the closure before and after lane signal operation were recorded. The comparisons cover 14 incidents before the signals and 8 incidents after. Freeway volumes were compared to assure similar traffic conditions. Table 2 gives a 39 percent increase in lane capacity for three-lane sections and a 32 percent increase for the four-lane section during operation of the lane signals. In the four-lane section, the shoulder lane is reserved for exiting traffic only

TABLE 3
COMPARISON OF AVERAGE TRAVEL TIMES¹ BEFORE AND
AFTER CONTROL SYSTEM INSTALLATION

Location	Car Method	Time Period	Avg. Travel Time (min)	Percent Reduction
Study section	Follow	Before peak	5.86	
		After peak	5.29	
		Reduction	0.57	9.7
		All before	3.98	
		All after	3.80	
		Reduction	0.18	4.5
	Floating	Before peak	6.17	
		After peak	4.88	
		Reduction	1.29	20.9
		All before	4.02	
		All after	3.68	
		Reduction	0.34	8.4
Extended areas ²	Follow	Before peak	3.24	
		After peak	1.86	
		Reduction	1.38	42.6
	Floating	Before peak	3.10	
		After peak	1.94	
		Reduction	1.16	37.4

¹Test vehicles only, northbound direction.

²Beyond study section (Merrick to Grand Trunk Railroad).

and is so signed. Thus, the increase in capacity for this section is actually higher than presented, as the average lane capacity reflects those vehicles in the shoulder lane for exiting as well as through traffic.

The preliminary results show a definite increase in freeway operation during such incidents which can be attributed to the control system. Continuation of this study is planned.

Travel Time Comparisons.—The travel time study was repeated following the installation of the control system. The basic plan of the study was to determine the feasibility and reliability of securing travel times through a 13-camera study area from television monitors. The weeks' study in April 1961 showed this could be done accurately. This was again confirmed in an after phase in July 1962. This after phase took place while the lane and speed signals were being used to maintain smooth maximum flow of traffic and to give maximum assistance to the traffic.

Use of several operators for the control system operation introduced additional variables which could not be measured. The study hours in the after phase were the same as in the before phase. In addition to the various passenger vehicles and trucks observed in the study, a State test vehicle again made runs through the study area and logged travel times in both directions at each camera location and at several points beyond each end of the study section. This allowed comparisons in the study area as well as in adjacent areas 1 mi to the north and 0.7 mi to the south. The data were obtained from computer tabulations coded on IBM cards.

TABLE 4
COMPARISON OF AVERAGE TRAVEL TIMES¹ BEFORE AND
AFTER CONTROL SYSTEM INSTALLATION

Location	Car Method	Time Period	Avg. Travel Time (min)	Percent Reduction
Study section	Follow	Before peak	4.92	
		After peak	<u>3.72</u>	
		Reduction	1.20	24.4
		All before	3.95	
		All after	<u>3.30</u>	
		Reduction	0.65	16.5
	Floating	Before peak	4.83	
		After peak	<u>3.88</u>	
		Reduction	0.95	19.7
		All before	3.74	
		All after	<u>3.35</u>	
		Reduction	0.39	10.4
Extended areas ²	Follow	Before peak	3.29	
		After peak	<u>2.85</u>	
		Reduction	0.44	13.4
	Floating	Before peak	3.47	
		After peak	<u>2.91</u>	
		Reduction	0.56	16.1

¹Test vehicles only, southbound direction.

²Beyond study section (Baylis to Glendale).

Tables 3 through 7 compare travel times to indicate any benefits attributable to the control system. Freeway volumes for the before and after periods were compared closely to detect the effects of any variable volume conditions.

Tables 3 and 4 give travel time comparisons by direction, driving method, TV-viewed area comparisons, and adjacent areas. Peak-period comparisons are separated from total observed periods (included off-peaks) and made for the test vehicles only.

Table 5 gives summaries of travel time comparisons for each direction of travel, showing the reduction in travel time effected in the areas immediately outside the study section. The results were obtained during control system operation. They are based on 800 travel time samples in the before period and 850 in the after. Indications are that definite reduction in travel time can be effected with the control system operation.

Travel time reduction can be expressed in time savings to motorists. Time savings present a more realistic factor which simplifies the understanding of the benefit of control system operation. Table 6 gives time savings based on travel time reduction, and expanded to total volumes through the study section, for each direction and for the areas

TABLE 5
TRAVEL TIME COMPARISON

Traffic Flow	Location	Time Period	Reduction in Travel Time (%)	
			Follow Car Method	Floating Car Method
Northbound	Study section	Peak	9.7	20.9
		All	4.52	8.45
Southbound	Extended area ¹	Peak	42.6	37.4
	Study section	Peak	24.4	19.7
		All	16.5	10.4
		Peak	13.4	16.1

¹Beyond study section (Merrick to Grand Trunk Railroad).

²Beyond study section (Baylis to Glendale).

TABLE 6
ESTIMATED TIME SAVINGS APPLIED TO STANDARD PASSENGER
VEHICLES ONLY, STUDY SECTION

Location	Length (mi)	Direction of Traffic	Travel Time Sample	Time Period	Time Savings ¹ (sec)	Total Pass. Vehicles	Total Est. Time Savings per Day (hr)
Study section	3.2	Northbound	500	14-hr	19	520,000 ²	273
		Southbound	350	14-hr	59	600,000 ²	880 ²
Merrick to Grand Trunk	0.7	Northbound	-	3:30-5:30 PM	34	11,200 ³	112
Baylis to Glendale	1.4	Southbound	-	6:00-9:00 AM	70	12,000 ³	217

¹Average travel time reduction per vehicle.

²For 14-hr period.

³Estimated daily.

TABLE 7
AVERAGE SPEED COMPARISONS, TOTAL TRAVEL TIME SAMPLES—
ALL VEHICLES

Direction	Average Speed (mph)		Increase	
	Before Signals	After Signals	MPH	%
Northbound	38	43	5	13
Southbound	38	48	10	26.3

outside the study section (passenger vehicles only). The samples were split equally between off-peak and peak periods. Traffic volumes for the 14-hr surveillance are used because the control system operated only for that period of time. The travel time reductions were obtained from IBM computers. Table 6 also gives estimated time savings if average travel time reduction is applied to passenger vehicles for an assumed 14-hr operation period.

Table 7 gives the travel time reduction in average speed comparisons for before and after signal operation. Both directions of travel indicate increases in average speeds. These speeds were computed from travel time samples through the study section.

Traffic Information Collection Equipment

The traffic data collection equipment provides the means of obtaining mass traffic information for research in freeway traffic characteristics and driver behavior. The project is preparing programs for various studies which involve mass data for use of computers. Because some of the studies completed were conducted with manual data collection and analysis, it has become apparent that future research must incorporate

TABLE 8
COMPARISON OF PEAK TRAFFIC VOLUMES BY DAY OF WEEK

Type of Volume	Volume on						
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
24-hour	64,785	63,880	66,265	66,250	63,000	59,411	43,214
Total rush (3 to 6 PM)	16,611	15,280	15,396	16,122	15,318	-	-
Highest hourly	5,815	5,283	5,630	5,629	5,487	5,145	3,721
Average rush hourly	5,537	5,092	5,132	5,374	5,106	-	-
Average daily hourly	2,699	2,662	2,761	2,760	2,624	2,475	1,801
Highest 15-min	1,537	1,405	1,429	1,469	1,423	1,393	1,018
Average 15-min:							
Rush period	1,384	1,273	1,283	1,344	1,277	-	-
24-hour	675	666	690	690	656	619	450
Highest 5-min	525	488	496	517	498	483	370
Average 5-min:							
Rush period	461	424	428	448	426	-	-
24-hour	225	222	230	230	219	206	150
Highest 1-min	114	104	108	113	107	105	87
Average 1-min:							
Rush period	92	85	86	90	85	-	-
24-hour	45	44	46	46	44	41	30

computer programing to avoid the painstaking, tedious, and time-consuming analysis. The possibility of obtaining traffic information simultaneously on volumes, speeds, and occupancy in such a quantity at several points on the freeway can be realized to the maximum degree with computer programing.

The present data collection equipment consists of sensing equipment and computers that collect data at two locations for three lanes in both directions. Such information will be useful in controlling traffic on the freeway by providing complete information on the character of traffic flow.

Freeway Volume Characteristics and Classification.—The research study on freeway volume characteristics and classification is an example of the use of the data collection equipment and illustrates the need for computer application. Its purpose is to obtain the basic volume information over the freeway study area in order to determine volume characteristics, volume trends, and patterns to be used as a basis for comparison of traffic after the signal control system is installed. The information will be used to determine freeway traffic characteristics and the reliability of sampling, thereby eliminating the need for obtaining complete sets of traffic data for future studies.

To reveal the characteristics of freeway traffic fully, it is important to understand how this traffic is affected by the various types of vehicles in the traffic streams. Each

TABLE 9
COMPARISON OF PEAK TRAFFIC VOLUMES

Period	Percent of	Volume				
		Mon.	Tues.	Wed.	Thurs.	Fri.
Rush ¹	24-hr total	25.6	23.9	23.2	24.3	24.3
Peak:						
60-min	24-hr total	9.0	8.3	8.5	8.5	8.7
	Rush period	35.0	34.6	36.6	34.9	35.8
15-min	24-hr total	2.4	2.2	2.2	2.2	2.3
	Rush period	9.3	9.2	9.3	9.1	9.3
5-min	24-hr total	0.81	0.76	0.75	0.78	0.79
	Rush period	3.2	3.2	3.2	3.2	3.3
1-min	24-hr total	0.18	0.16	0.16	0.17	0.17
	Rush period	0.69	0.68	0.70	0.70	0.70

¹For northbound flow occurs from 3 to 6 PM.

TABLE 10
COMPARISON OF PRESENT PEAK VOLUMES TO DESIGN CAPACITY

Period	Percent Volume Above Design Capacity						
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
Rush	23.0	13.2	14.0	19.4	13.5	-	-
Peak:							
60-min	29.2	17.4	25.1	25.1	21.9	14.3	- ¹
15-min	36.6	24.9	27.0	30.6	26.5	23.1	- ¹
5-min	40.0	30.1	32.3	37.9	32.8	28.8	- ¹
1-min	52.0	36.0	44.0	50.7	42.7	40.0	16.0

¹Volume below design capacity.

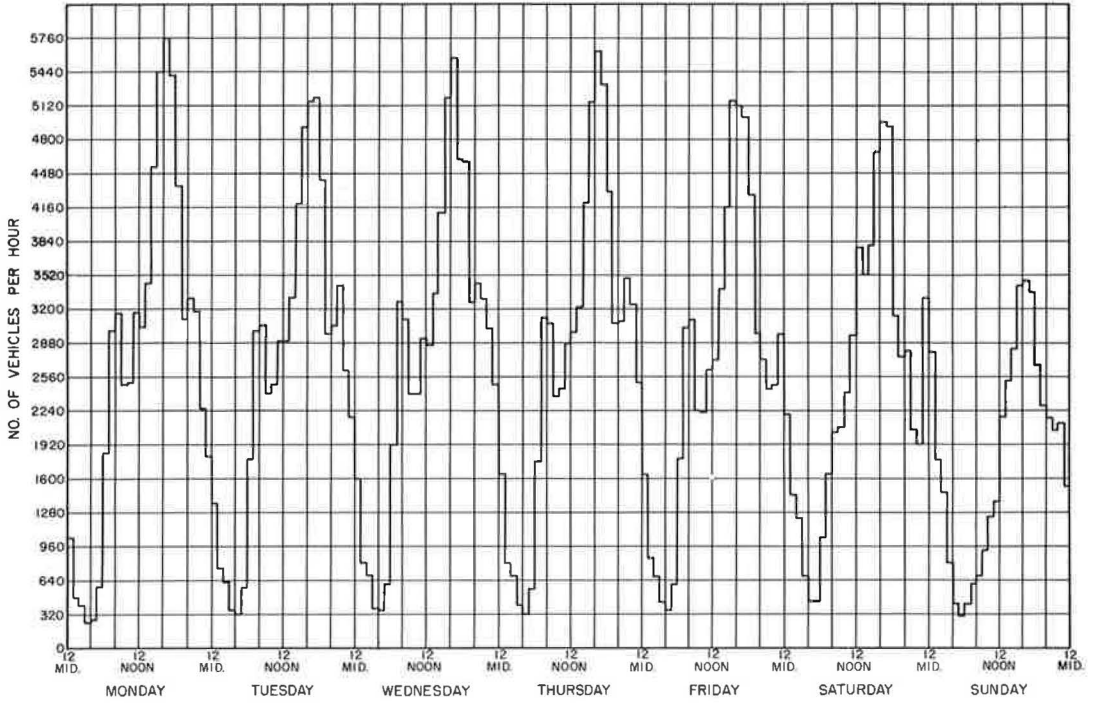


Figure 7. Hourly volumes for 7 days, John C. Lodge Freeway, outbound.

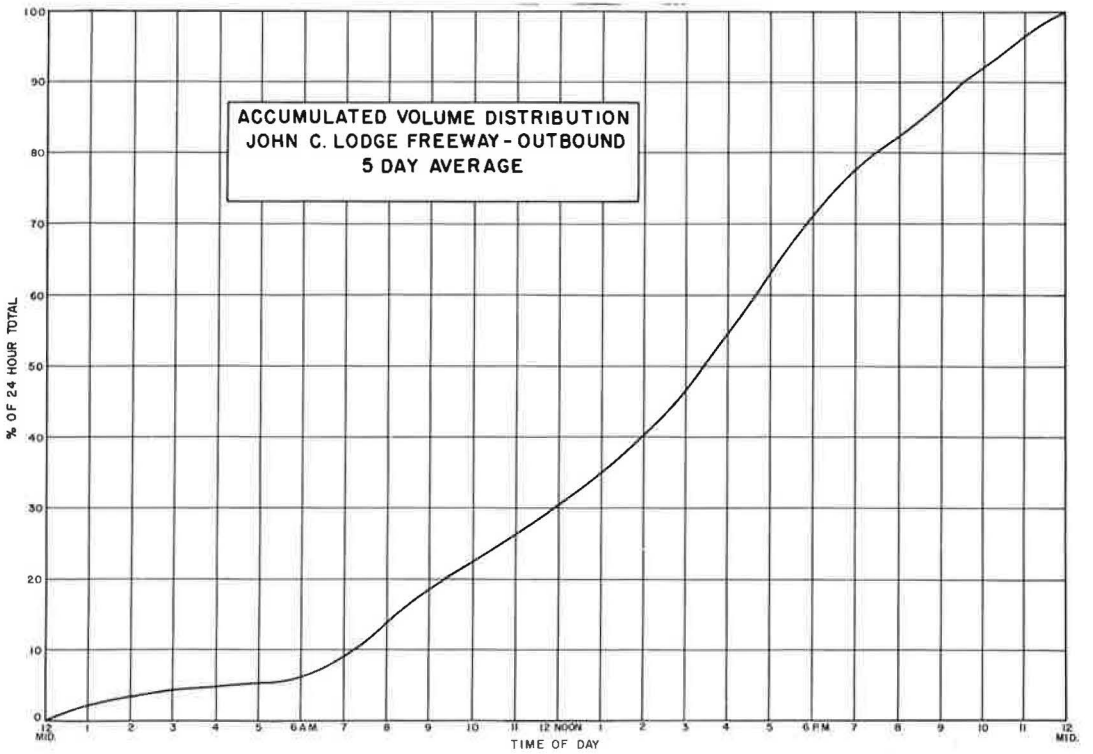


Figure 8.

type vehicle has individual operating characteristics which introduce certain influences on the traffic stream. It is important to know what proportion of the traffic stream is made up of each type of vehicle.

Volume classifications were also determined for various lanes, on- and off-ramps, and different sections of the study area. The major portion of the study was conducted with the use of the automatic sensing equipment to obtain 24-hr volume counts on the freeway proper. This equipment had to be supplemented with machine counts on all ramps and with manual classification counts for nine vehicle types.

A supplemental phase of the study determined that it was possible to obtain accurate traffic information, volume counts, and vehicle classification by use of television. Television observation was particularly helpful in obtaining sampling counts over short periods of time for determining reliability in sampling future traffic volumes on the freeway. Programs are under way using computers to handle the mass data available from the study.

Tables 8 through 10 and Figures 7 and 8 give some indication of volume conditions on the freeway. The data were collected over seven consecutive days for the northbound direction only, entirely by use of the automatic sensing equipment and detectors.

Table 8 compares peak traffic volumes by day of week. Comparisons are made by 1-hr, 15-min, 5-min, and 10-min periods. Table 9 compares the percent of peak volumes according to 24 hr, and the rush period from 3:00 to 6:00 PM for the weekdays only. Table 10 compares present peak volumes to design capacities of the freeway. The comparison is made for weekdays by percent increase over design capacities.

Figure 7 shows the hourly volumes for seven days. Figure 8 shows the accumulated volume distribution of traffic for five weekdays collected thus far. The curve shows the 5-day average by percent of 24-hr total.

A program of continuous collection of traffic data for computer application is in progress.

CONCLUSIONS AND RECOMMENDATIONS

The preliminary conclusions of this study are as follows:

1. The television system has become extremely important in the operation of a freeway control system. The benefit of continuous viewing of the freeway for the efficient operation of such an intricate and complex control system cannot be stressed enough, as exemplified by speedy detection of emergency situations.
2. The television system provides an opportunity to obtain valuable experience for studying freeway traffic from continuous visual observation of a length of freeway, and also for the accumulation of research information that cannot be obtained in any other manner.
3. The traffic control system has indicated that it will provide increased freeway operation efficiency based on the following: (a) More efficient handling of lane closures as evidenced by increased capacity (35 to 40%), advanced warning resulting in advanced merging and in the reduction in number of vehicles trapped at a closure. (b) Significant reduction in travel time under control system operation during incidents, lane closures, and normal conditions (5 to 25%).

This is a preliminary evaluation based on research activity to date; further research is required and recommended, particularly in the area of control system evaluation. A total evaluation will be necessary after installation of ramp signals, whose effect could be significant.

Time has not permitted the proper evaluation of the speed control phase on which the absence of the ramp control has a direct bearing. Further, with the additional information from individually-controlled, equally-spaced speed detectors, speed control should be more realistic and efficient.

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