TOMORROWS TRAFFIC

FREEWAY TRAFFIC SURVEILLANCE RESEARCH PROJECT

BY

EDWARD F. GERVAIS, TRAFFIC RESEARCH ENGINEER

MICHIGAN STATE HIGHWAY DEPARTMENT

July, 1960

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The application of electronics to tomorrows traffic can be divided into two catagories. In one application electronic equipment can be used to gather information and make it known to the driver by some system of communication so that he can better adapt himself to the traffic stream. The second application is the use of electronic equipment to guide or influence the operation of the vehicle itself. This paper deals with the first application.

Freeway design and traffic operation presents one of the biggest challenges confronting the transportation industry. The accellerated road building program is concentrating large portions of the total budget on this type of construction based on the premise that the greatest transportation benefits will be obtained from this type of roadway. Although much valuable knowledge has already been gained from freeways now in existence it is only honest to admit that this is the area in which the greatest lessons are yet to be learned.

The whole concept of a freeway is to build a roadway which will handle large volumes of traffic with celerity and safety. The older type highways were often times required to handle large volumes of traffic through pure necessity. This resulted in sad deterioration in safety patterns and the lengthening of travel time for the motorist using the facility. Certain evidence began to come to light as to those elements in design and traffic operation which caused the increase in accidents and a reduction in efficiency whenever traffic volumes approached saturation. The freeway design of today is a result of the experience gained from observing the operation of the older type highways.

In general, it can be stated that the new type of highway operates quite satisfactorily when design volumes are not exceeded, but those segments of freeways which are forced to carry traffic volumes in excess of their intended volumes tend to nullify their advantages at the times when their need is the most critical. Those portions of freeways most subject to over saturation of traffic are generally centered in urban areas. Regardless of the location of the freeway, the troubles which result when certain critical densities of traffic are reached are generally the same. At one moment we have moving lanes of traffic carrying large volumes of traffic at speeds in excess of 40 m.p.h. Traffic volumes keep building up until the speeds drop off suddenly and in one moment a swiftly moving traffic stream is converted to a situation where vehicles are crawling along bumper to bumper. Traffic volumes taken under these circumstances generally reveal that the volumes are considerably under those obtained when the traffic stream was moving free of impediments. The traffic engineer cannot say at this point that there is just too much traffic and let the problem drop. Common sense tells us that if we could preserve the free movement of traffic we would actually be able to accommodate more traffic volumes than are obtained when we allow the traffic stream to go into semi-static conditions such as are present under congested traffic conditions. The fact that something can be done about this traffic condition is in reality the real reason why the freeway traffic surveillance project, which is now underway in the City of Detroit, came into being.

The second factor which gave inpetus to the project was the rapid development of television which compelled forward-thinking individuals to believe that this could be one of the answers to the freeway traffic problem. Early experiments conducted in the City of Detroit reveal that television would prove of great benefit since it would permit a single operator to simultaneously view a large portion of a freeway. While the quality of the picture would not permit the recognition of such minute details as license plate numbers, etc., this information was not necessary for obtaining valuable information from video pictures. Nighttime pictures were found to be of sufficient quality to permit identification of trouble areas which may develop as a result of accidents, disabled vehicles, and traffic stoppages. The proof that a good picture could be obtained of the road surface and its vehicles was not in itself sufficient to endorse the use of television. While it is true that an operator seated before television monitors could summon emergency vehicles and police aid to motorists in need of such services, traffic experts were generally of the opinion that this feature alone could not warrant its high cost. The best use of a television system seems to be in combination with a signal system whereby motorists can be given instructions controlling his entrance and exit from the freeway along with lane usage and speed control on the freeway proper.

Again the valuable experimental work carried on in Michigan with devices of this type made it logical to make a simultaneous study of television and freeway control in an area where there was experience and developmental facilities.

On this basis, the U.S. Bureau of Public Roads assigned to the Michigan State Highway Department a research project which was to prove the feasibility of the use of television along with the practicability of a freeway traffic control system. The evaluation of these two types of devices made it necessary to measure their influence on traffic behavior of drivers using the freeway. The instrumentation required to make such observations would also permit comprehensive studies of driver behavior under the influence of freeway design elements and a traffic control system. The research which could be gained from this experiment was made the third and one of the most important phases of this research project.

Detroit, as the motor capital of the nation, is an ideal location for freeway traffic research. Living up to this title, it depends on the automobile as the principal form of transportation for its many inhabitants. The John Lodge Freeway, which will be the trial ground for the freeway traffic surveillance research project, has its beginning at Jefferson Avenue in the heart of the new Civic Center area. At the present time, the freeway ends at Wyoming Avenue, however, construction is now in progress for the extension of this freeway to a point north of Eight Mile Road. The area which will be under television surveillance and signal control will be 3.2 miles long and will be between the interchange of the Edsel Ford Freeway and the Davison Freeway. This will require the installation of 14 television cameras, 11 sets of overhead lane and speed control signals and 9 ramp closed signals. The lane control signals will be mounted overhead in advance of 11 off-ramps in the area which will all be in view of the television cameras.

In addition to the above mentioned equipment, there will also be speed and sensing devices which will be gathering information at predetermined points to show the behavior of traffic under various traffic conditions. The circuitry and equipment has been designed so that this type of information can be gathered simultaneously at several points and can be broken down by individual lanes. It will be possible to move the sensing devices to several locations on the project and to vary the combinations so that a full range of research information can be obtained. This will show the effects of various traffic variables during the course of the project.

The nerve center for the equipment used on the project will be a well equipped control room located in a building just west of the Gladstone Pedestrian Bridge. All video lines and circuits for the signal and traffic sensing devices will be brought to this point. This requires 2 cables of approximately 2" in diameter, which will have 8 balanced pair of video circuits of No. 22 wire size. The control center is located approximately at the mid point of the project. One cable will go to the north while a second cable will go to the south of the project. The 2 extra video circuits will permit us to experiment with newly developed television cameras and different mounting positions while maintaining operation on the 14 permanent cameras. This will permit us to evaluate whether new camera development are providing features which will be necessary or desirable in future work of this type and also to experiment with various camera mounting positions to determine optimum viewing of freeway traffic. Much hard work has gone into the development of the television, signal control and research equipment intended for use on this project. One of the big problems was to create a variable signal system which could influence freeway traffic and thereby cause it to respond to a control operator in accordance with traffic demands. On the freeway proper there are two types of control which seem capable of producing positive benefits. One is lane usage. By this we mean the dissemination of information to a driver which tells him when he may drive or stay off a lane. This information is particularly of benefit in times of emergency since multiple rear end accidents are all too prevalent on the freeway. If a motorist could be given information of traffic stoppages ahead of him he could move out of those lanes which are blocked and use those available for travel in a more leisurely manner under greater safety. In case there is a complete blockage of the freeway it would be possible under such a control system to decrease one at a time the number of lanes available to traffic until the point is reached where the traffic blockage occurs. This would permit traffic to leave at more than one exit in advance of the trouble and eliminate the situation which exists today where all traffic comes to the point of blockage and attempts to leave on a single exit ramp.

The development of lane signals which would clearly give a motorist instructions as to whether a lane could be used or not was a problem in itself. The selection of the proper symbols to be used on such signals was based on a research project conducted by Michigan State University and the Michigan State Highway Department in cooperation with the Bureau of Public Roads. After the symbols were selected by laboratory techniques they were given a practical test for the first time on the system of lane control employed on the Mackniac Bridge. These signals called for a red "x" to tell drivers they cannot drive a lane while a green "arrow" tells him he can use the lane. These signal symbols have now been adopted as a national standard for lane control signals.

The selection of the proper symbols is one thing, but how to properly display them to the public on a well designed signal is another one. We have conducted numerous tests on lane signals for every conceivable type of light source. These tests are rapidly nearing completion and we feel certain that the lane signals which will be displayed on the John Lodge Freeway will represent the best possible on today's market.

The final element of control for freeway traffic is the variable speed. Speed is very important since we have already learned that urban freeway traffic conditions permit speeds of 55 m.p.h. with safety. Whenever this speed is decreased due to heavy traffic conditions, the drivers should be properly informed and a speed message displayed which is best applicable to circumstances. We have initially selected 40 mp.h. as a speed most representative of high volume driving conditions. If, in the course of the project, a different speed message is determined to be more appropriate, our speed signal design will permit the changing of the speed message in a very simple manner. 25 m.p.h. has been selected as the emergency speed. This speed message will be displayed whenever there are traffic troubles or hazardous driving conditions created by weather. One pair of lane signals will be placed over the center of each driving lane while one set of variable speed messages will be displayed above and on the center of the signal span carrying these signals. We have one choice of three speed messages to be shown simultaneously to all lanes of the freeway as a result of preliminary investigations. These show that variations in speeds between the various lanes are not as great as previously believed. Also, that attempts to place all slow moving vehicles in the right hand lane is actually creating traffic problems on the freeway since clustering of these vehicles on the right lane proves to be an effective barrier to traffic trying to enter at entrance ramps. If such traffic comes to a stop while awaiting a gap in the right hand lane of the freeway, we have a bad traffic problem resulting when the traffic attempts to enter the freeway from a standing start. Also, the large amount of weaving prevalent in an urban freeway requires traffic in the various lanes to move at approximately the same speed. Attempts to establish different speeds for the various lanes could prove to be very confusing to the average driver.

The budget allocated for this project totals $400,000 distributed over a 2 year span. Due to the highly developmental nature of both the television and the signal equipment, the project committee found it necessary to procure the equipment under two separate contracts. The first contract represented the procurement of all television equipment including both cameras, amplifying equipment and monitors along with cable for the entire project. Since the circuitry for all equipment used could be grouped in one cable, we found it feasible to do it by this method. The necessity of buying by low bid required that very thorough specifications be written covering the equipment. Prior to the writing of the specifications, very exhaustive work was done in our organization by well qualified personnel. We feel that the final specifications are a tribute to the splendid work performed by the people on this project. The successful bidder was the General Electric Corporation, which offered one of their latest vidicon type television cameras. This camera was a result of development made for the missile program and the extreme ruggedization of this equipment made its use ideal for the freeway project. The camera is completely transistorized except for the vidicon tube. The camera proper is very compact which makes it easy to mount it in an environmental housing which will be heated and ventilated to maintain temperatures between 70 and 100 degrees, Fahrenheit. The enclosures will be weather-proof and vandal proof. The camera will take pictures through a pane of glass mounted in front of the lense and will be equipped with windshield wipers. The greater number lines of resolution of this television system will permit a picture of greater clarity than that enjoyed on a home television screen. This greater clarity will permit the identification of individual vehicles with great ease under daytime viewing conditions. Due to the research nature of the project, we felt that we needed the best picture possible with reasonable cost for fear that a picture of lesser quality might not reveal the value to be received from television surveillance. The nighttime picture will provide sufficient detail to detect stopped vehicles both on the traffic lanes and the shoulder, along with considerable additional details. In some of our nighttime tests, we have been able to show vehicles parked on the shoulder and clearly reveal the movement of people walking in the area of the disabled vehicle. All video information will be brought back to the control center and displayed simultaneously on 14 monitor screens. Provisions are made so that a 15th monitor can be included in the viewing room. One of the uses of the 15th monitor is for recording purposes. It is our intention to set up this monitor so that views will be received from each of the 14 cameras in sequence. An objective of our research is to prove whether the simultaneous viewing of monitors or the sequence viewing would prove most satisfactory in an expanded freeway traffic surveillance system.

The second phase of our project will require the installation of the signal equipment. The type of control proposed for this project by its very nature means that a control operator seated in the monitor room will select signals remotely. This immediately presents many problems not prevalent in ordinary traffic signal systems. First, the selection of the signals by the operator must preclude any false selection of signals. To accomplish this, the control is designed so he may select signals and signal span then scan his choice before the pulses are sent out to the signals at the remote locations. This requires a panel board which will display signals which he has selected. After he has assured himself that the signals are correct he presses an activating buttom which causes the control equipment to respond and send the messsges to their proper signal spans. The fact that the signal messages are sent does not necessarily mean that they have been received at the span, therefore, a confirming system must also be a portion of this control. These features have all been incorporated in the design of the controller and like in the television equipment, complete specifications are written and bids will be taken in a matter of weeks.

The third type of equipment for the project represents the traffic sensing devices, and recording equipment to be used on the project. Since much of this equipment is also tailor made, the project committee has examined all types available on the market along with new developments in the field. The type and quantity of information needed for such a project requires that the equipment be very reliable and the data placed in such a form that it can be easily interpreted without tedious analysis. Computer equipment designed for use with the sensing equipment will be incorporated. We have had the benefit of experience gathered by the manufacturers of all three types of equipment mentioned. The cooperation has been tremendous and without their help we feel certain that we would not be at the stage that we find ourselves today.

One item of extreme importance is the maintenance of the equipment which will be installed along the freeway. The problem which freeway traffic will present to any maintenance crews cannot be over emphasized. This made it very necessary that extreme importance be given to mounting positions, ruggedization of equipment and methods by which maintenance crews would have access to the equipment. Although this project will probably produce future lessons on this feature, we have attempted to anticipate as many as possible in order that maintenance crews would be spared any undue risk. It would hardly appear logical to advocate the use of equipment, which while giving traffic benefits in one direction, would introduce hazards by its upkeep.

Time does not permit us to discuss all the problems involved in arriving at the equipment of our choice,but in order that our experience will not be wasted, all of our work is being documented so that any future work of a parrelling nature will have the benefit of our findings.

It is well at this point to explain what we hope to accomplish on this project. Under television monitoring, it will be possible to see simultaneously the entire length of the area on the John Lodge Freeway selected for this project. If there are any vehicle breakdowns or accidents, the operator will be able to detect this and if conditions require, shut off lanes of traffic to reduce accident potential in the breakdown area. There is a condition of traffic, however, which the operator may not be able to sense from the monitor screens. As we mentioned earlier, as traffic volumes get heavier they suddenly reach a critical density in which speeds fall off sharply and congestion ensues. Since density is a combination of volume and speed the operator could not be able to recognize such an occurrence especially when required to view 14 monitor screens. For this reason, we intend to have our speed and volume sensing devices spaced along the freeway in such a manner than an alarm system will give him warning of approaches to critical density. He will then be able to vary the rate of input of vehicles at the entrance ramps to the freeway by the ramp signal system. It is hoped by this method that those volumes of traffic which are permitted to enter the freeway will always be such that the freeway will be retained in a fluid operating condition underneath critical density levels. In case the ramp will be closed for a period of time it will then be necessary to display the "ramp closed" signal. Under these circumstances we also intend to augment the "ramp closed" signal by a gate which will be lowered across the ramp to offer a physical barrier to the motorist attempting to enter the freeway against the commands of the signal. In order to accommodate the motorist who will not be able to enter the freeway at a particular ramp it is our intention to establish bypass routes over the arterial street system. In order for these streets to handle this overload of traffic diverted from the freeway, we intend to alter the traffic signal timing on these arterial routes so that they will receive a longer green portion of the traffic signal cycle. This can all be accomplished by the control operator back at the control center. By preserving fluidity of the freeway traffic stream, we hope to shorten travel time and also permit the handling of greater traffic volumes than that now accommodated under the present system where traffic is allowed to congest.

Our present progress schedule calls for the television system to be completed near the end of December. The signal system will be placed under contract by that time and should be ready for operation by the first of June, 1961. The lapse of time between the installation of the television and signal equipment will permit us to study traffic behavior before the signal system is installed as compared to the traffic behavior after the signal system is installed. A comparison of the results should give us a clear picture of whether a traffic control system for freeway traffic will produce benefits resulting in greater carrying capacity and safety. Policies and procedures of the project will be determined by a committee, while a technical organization will carry on the work of the project. Representatives from the Michigan State Highway Department, the City of Detroit, and Wayne County are represented in both of these groups. Periodic reports will be made showing the progress of the activity so that this information can be disseminated to the general public. The work will be continued over a 2 year span. It is our hope that the information discovered and gathered throughout the course of this work will gain much valuable experience in data needed to not only operate but to design future freeways with greater safety and efficiency for travel by the motoring public.

The John C. Lodge Freeway

Traffic Surveillance and Control Research Project

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BACKGROUND INFORMATION

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In cooperation with the Bureau of Public Roads, the John C. Lodge Freeway Traffic Surveillance and Control Research Project 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, initiated in July 1960, was originally programmed for two years. The study section for this Project consists of 3.2 miles on the John C. Lodge Freeway, between the Edsel Ford Freeway and the Davison Freeway in the City of Detroit. This section includes portions of 3- and 4-lane freeway and 9 off-ramps and 9 on-ramps spaced at various distances throughout the study area.

The major purpose of the Project is twofold:

(1) The application of the latest developments of electronic and other related technological equipment in order to increase the operational efficiency on the freeway. Included in this equipment is the closed circuit television network and the traffic control system of lane signals, speed signals, and ramp closure signals.

(2) The evaluation of the effectiveness of the equipment in obtaining increased efficiency in freeway operation.

Directly related research, centered upon the study of freeway traffic characteristics, 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 upon freeway operation efficiency. For this purpose, traffic data collection equipment, consisting of sensing and computer equipment, is available on the Project through loan from the General Railway Signal Company.

Project Instrumentation

The major project activity during the past two years has been directed toward the development and procurement of the instrumentation for the Project. As a result, this instrumentation is the latest and most effectual of its kind and affords a laboratory for research in freeway traffic study and control that cannot be equaled anywhere. Application of this equipment to this use has been the first of its kind in existence and the development of much of this equipment was performed on the Project.

The Project instrumentation and equipment can be grouped into three basic categories:

(1) Television Surveillance System,
(2) Traffic Control System, and
(3) Traffic Information Collection Equipment.

Television Surveillance System

The television system was installed in December 1960, after considerable investigation into design of equipment to meet the requirements of the Project.

There are 14 television cameras spaced approximately 1/4 mile apart to provide viewing of the entire study area. Reception from the cameras is transmitted to one central control point located about midway in the study section. In the television control center, 14 monitors are in operation to receive the video transmission from the 14 cameras. Remote control of camera functions allows the operator to change from normal lens to a telephoto lens, to focus each camera when necessary; permits the panning and tilting of each camera, that is, moving the camera right or left or up or down as the situation may require; and also provides control of a remote iris on each camera which regulates the amount of light received by the vidicon tube. In addition, the television system provides for the automatic sequencing of the picture on the 14 monitors and with the use of the spare monitor available, sequencing operation can be viewed independently of the 14 regular monitors.

Television surveillance has proven to be a very efficient detection system, with regard to incidents such as accidents, vehicle breakdowns, etc., which occur frequently on the freeway; and thus has aided greatly in the operation of the control system to effect any corrective measures necessary. Surveillance, detection, and corrective action can be accomplished in a matter of seconds and the operator can evaluate, visually, the results.

Without television surveillance, it would be extremely difficult to operate a traffic control system as complex as the system existing on this Project.

The Traffic Control System

The traffic control system of lane signals and speed signs was installed in the spring of 1962. Operation began on May 7, 1962. The ramp closure signals, which are part of the control system, were installed this spring (1963). The system includes 11 lane control signals, 21 variable-speed signs, and 9 ramp controls.

Lane Control Signals

Lane signals utilize the red "X" and green arrow, which are the new national standards for signals of this type. The red "X" means the driver must leave the lane in which he is driving as soon as it is safe to do so. He may move over to a lane which displays a green arrow, and this may be either a through lane or a lane leading to an exit ramp at the location where the signal span is installed. The green arrow means that the lane is open to traffic but does not mean the driver has a route which guarantees him complete absence of traffic stoppages. For obvious reasons, the red "X" is not employed unless the lane is closed for maintenance or some emergency such as an accident. The lane control signals are installed at eleven locations in the study section, six for the northbound direction and 5 for the southbound.

Variable-Speed Signs

A variable speed sign is utilized in conjunction with the lane signals. This sign has been designed to permit speed messages to be displayed in increments of five miles per hour from 20 to 60 miles per hour. Appropriate speeds to be shown are determined by the operator's analysis of information from sensing equipment on the freeway. There are 21 locations where the variable speed sign is installed; 11 for the northbound direction and 10 for the southbound. In some instances, it is installed with a lane signal span and, in other instances, by itself.

Ramp Controls

Ramp signals are installed on each of the 9 on-ramps in the study section--4 northbound and 5 southbound. The signal presents the legend "Don't Enter" and enables the operator to close a ramp if congestion or an incident has occurred on the freeway in the close proximity of an on-ramp. Traffic from this ramp can be diverted along an alternate route until it can conveniently enter the freeway. The signal is the blankout type with a legend plate "Ramp" attached to the bottom of the sign.

Supervisory Control

The control console, located at the TV Control Center, provides remote-control activation of any signal, speed sign, or ramp signal at the respective locations in the field.

The operator is provided with a confirmation panel which displays, on a schematic of the freeway section under study, the location of lane signals, speed signs, and ramp signals. This panel, through the supervisory control circuitry, informs the operator that the function selected to provide the corrective measure has been properly sent and indicates, with positive confirmation, that the message has been received and is not in error. Because of the critical nature of any action which causes a change in the freeway traffic flow, it is obvious that it is necessary for the control system to possess such a means of positive confirmation for the messages sent to the field.

Traffic Information Collection Instrumentation

Through the generosity and cooperation of the General Railway Signal Company, the Project has the use of a laboratory of electronic instrumentation, the latest of its kind, providing the means of obtaining traffic information including volumes, speeds, and occupancy. This equipment has been loaned to the Project on an indefinite basis and comprises the third category of instrumentation utilized.

This equipment consists of automatic sensing and computer equipment. It utilizes ultrasonic sensors for vehicle detection. The impulses from these sensors are 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 tabulating and analysis at a later time. This equipment not only provides information on lane speeds, lane occupancy, lane minute volumes, freeway occupancy, freeway volumes, freeway average speeds, but also provides total vehicle counts and distinguishes between passenger vehicles and commercial vehicles.

PROJECT RESEARCH ACTIVITIES

Research activities for this Project have been directed into the following areas:

(1) Evaluation of Television System.
(2) Evaluation of the Traffic Control System.
(3) Evaluation of Traffic Information Collection Equipment.
(4) Study of Freeway Traffic Characteristics.

Research in all areas is interrelated and has been useful in combined evaluations.

AN ANALYSIS OF RANDOM FREEWAY TRAFFIC INCIDENTS
-- ACCIDENTS AND VEHICLE DISABILITIES

A B R I D G E M E N T

For
Presentation at the Annual Meeting of the
Highway Research Board
in January 1964
Washington, D. C.

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December 1963

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A B R I D G E M E N T

Introduction

The John C. Lodge Freeway Surveillance Project television system provides continuous viewing of the 3.2 miles of study area on the Freeway. Trained observers are on duty for a 14-hour period from 6:00 a.m. to 8:00 p.m. daily, except weekends and Holidays. A General Log is maintained as a permanent record of all vehicular incidents; including accidents, vehicle disabilities, maintenance operations, and others such as motorists aiding distressed vehicles. This Log contains all the data for this study and analysis of freeway incidents.

Purpose

The purpose of this study is to determine the frequency, duration, and character of random freeway traffic incidents; and also to investigate the factors influencing their occurrence.

Study Data

The study data, taken from the General Logs, covered a period of one year (255 surveillance days) from June 1, 1962, to June 1, 1963.

Analysis of Data

The analysis consisted of a presentation of total incidents, accidents, and vehicle disabilities; compared as to location related to 4-lane vs. 3-lane sections, weather conditions, pavement surface temperature, aid received, lane in which incident occurred, day of week, month of year, and time of day. Vehicle disabilities included stalls, flat tires, spin-outs (vehicle spinning on slippery pavement, no collision occurring), and others.

Incidents by Location

A comparison of incidents in the 4-lane and 3-lane sections reveals greater frequency, reflected in daily averages, in the 4-lane section, as follows:

1. 4-lane section = .69 incidents per mile =
   .16 accidents and
   .53 vehicle disabilities.

   3-lane section = .51 incidents per mile =
   .13 accidents and
   .38 vehicle disabilities.

2. 4-lane section = 11.9 total incidents per million vehicle miles =
   2.8 accidents and
   9.1 vehicle disabilities.

   3-lane section = 8.7 total incidents per million vehicle miles =
   2.2 accidents and
   6.5 vehicle disabilities.

Comparison of total incidents, by lane, revealed that 45.7% occurred in the median lane--more than twice those in lane 2 and lane 3. Forty-seven percent of the accidents occurred in the median lane; 44% of the vehicle disabilities occurred in the median lane.

Incidents by Time of Day, Direction of Travel, and Day of Week

As expected, the frequency of incidents was greater during the time of day when the heavy volumes occurred and the greatest number of incidents occurred during the periods when maximum density of the freeway was exceeded. More analysis of the volume and density relationship to incidents is planned for the future.

Neither the direction of travel nor the day of the week had any significant influence upon vehicular incidents.

Vehicular Incidents Related to Climatic Conditions

The greatest number of incidents occurred during the months when driving conditions were made more hazardous by low temperatures or sudden changes in the weather.

Compared to dry conditions, there were twice as many incidents per day per mile when the pavement was wet and four times as many when the pavement was slushy. There were three times as many incidents per day per mile when it was raining and almost six times as many when it was snowing.

Comparison by temperature indicated the frequency of total incidents, at below 30°, was 60% more than above 30°.

As compared to dry pavement, the number of vehicle disabilities occurring on wet pavement were almost doubled and, on slushy pavement, were $4\frac{1}{2}$ times as frequent. Judging solely on weather conditions, the frequency of vehicle disabilities almost tripled during rainy weather and increased by almost 6 times when it was snowing. During temperatures below 30°, the vehicle disabilities were almost 1.6 times that above 30°.

The frequency of accidents, when the pavement was wet, was about 3 times the number when it was dry; and during slushy conditions, it was almost 5 times as much.

The frequency of accidents, by weather conditions, was increased, over 3 times in rain and 6 times in snow, over the number in clear weather. For below 30° temperature, the frequency of accidents was almost double that for above 30° temperature.

Duration of Incidents

The average duration for the total 927 incidents was 5.24 minutes; the median value was 3 minutes. Thirty-eight percent of the total incidents had a duration of 3 to 10 minutes; 12% had a duration of 10 minutes or more.

The average duration of 229 accidents was 6.14 minutes; 86% of the accidents had a duration of less than 10 minutes.

The average duration of vehicle disabilities was 4.94 minutes; and 90% of the vehicle disabilities had a duration of less than 10 minutes.

Vehicle Incidents and Type of Aid

Examination of the type of assistance needed by the motorists involved in incidents showed that 46% of the motorists moved their vehicles to the shoulder by themselves or continued on the freeway, 43% needed a tow or push, and 11% waited in the lane for official aid even though their vehicles were in a condition to be moved. There was a gradual increase of motorists in the last category as the incident occurred farther from the shoulder (3% in the shoulder lane and 14% in the median lane).

The 698 vehicle disabilities included 593 stalled vehicles. Of these 593 stalled vehicles, 41% of the motorists were able to restart their vehicles and either continue on the freeway or move to the shoulder; 55% received aid from another motorist or wrecker; and only 4% waited for official aid before driving to the shoulder.

Out of a total of 229 accidents, 52% of the situations were resolved by assistance provided by the involved motorists; 24% needed a tow or push; and 24% waited for officials to arrive even though they were able to move the vehicles to the shoulder under their own power. Again, a high percentage of accidents, occurring in the median lane, were movable but motorists waited for official aid. The relationship of lane of incident location and type of assistance required and received will be studied further to supplement this paper.

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