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16. ABSTRACT

Early in 1967, Representative John Blatnik signaled a major change in thought in the approach to freeway systems when he noted:

The basic role of the State Highway Department is not to construct highways, although that is one of their major functions. They are, in the final analysis, in the business of operating a physical plant of highways.

Since the inception of the interstate freeway system in 1956, highway organization have evolved policies and procedures necessary for the planning, design, construction and maintenance of this complex freeway system. Most states have developed outstanding highway organizations capable of effective implementation of this planning, design, construction and maintenance concept.

However in the early sixties, something happened. We began to develop serious congestion problems on our urban freeways. In 1965, we set up an organization to find out how extensive the problem was and to find out just what could and should be done about it. We believe that planning, building and maintaining is not adequate and that any real systems approach to better freeways must provide for conscious, concerted operation of the freeway system. The new concept must be planning, building and operating.

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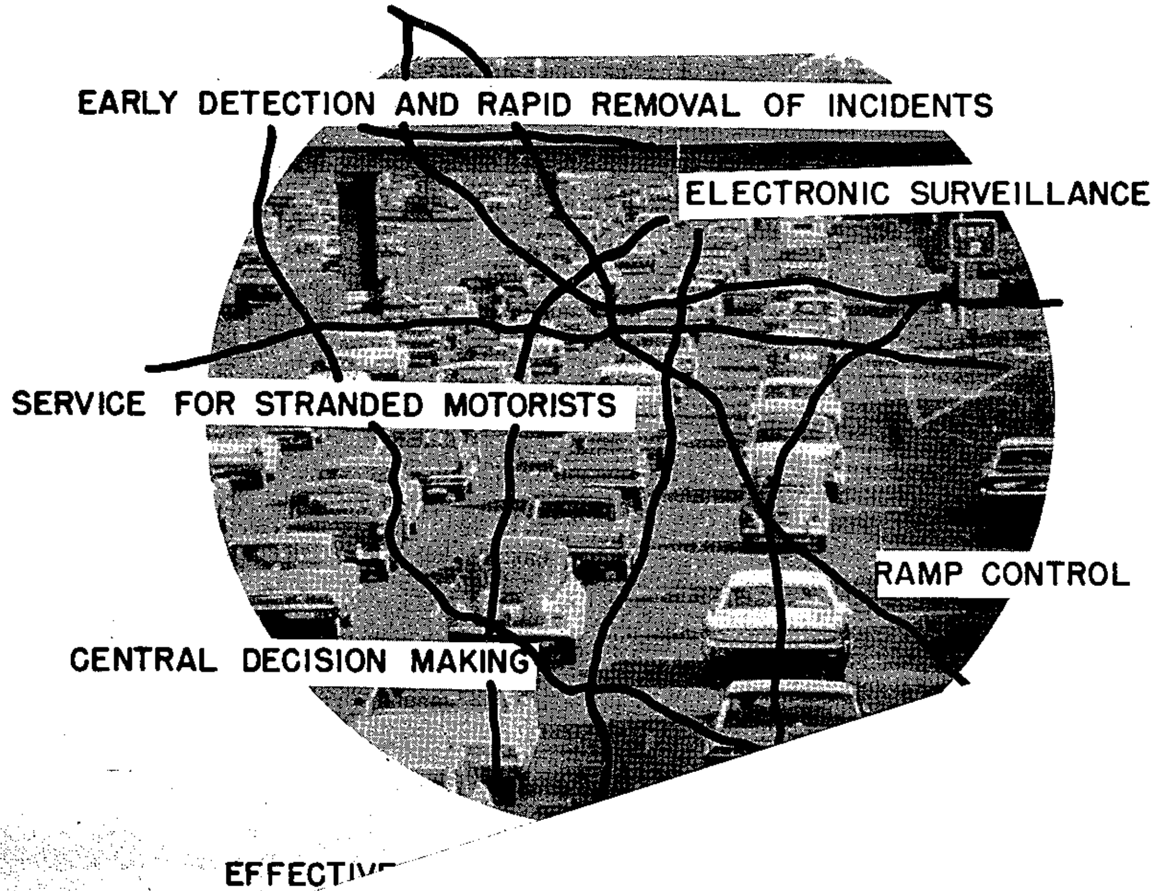

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DEVELOPING ...

MANAGEMEN ... **_GELES_**

...ESENTED BY: LYMAN GILLIS

TO: AASHO COMMITTEE JOINT SESSION
COMMUNICATION AND ELECTRONICS COMMITTEE
TRAFFIC COMMITTEE

HOUSTON, TEXAS
NOVEMBER 10, 1970

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DEVELOPING AN EFFECTIVE FREEWAY TRAFFIC MANAGEMENT SYSTEM FOR LOS ANGELES

BY BILL SCHAEFER AND JOHN WEST*

INTRODUCTION

Early in 1967, Representative John Blatnik signaled a major change in thought in the approach to freeway systems when he noted:

> The basic role of the State Highway Department is not to construct highways, although that is one of their major functions. They are, in the final analysis, in the business of operating a physical plant of highways.1/

Since the inception of the interstate freeway system in 1956, highway organizations have evolved policies and procedures necessary for the planning, design, construction and maintenance of this complex freeway system. Most states have developed outstanding highway organizations capable of effective implementation of this planning, design, construction and maintenance concept.

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* Mr. Schaefer is Assistant District Engineer for the California Division of Highways in Los Angeles. Mr. West is District Freeway Operation Engineer for the Los Angeles area.

However in the early sixties, something happened. We began to develop serious congestion problems on our urban freeways. In 1965, we set up an organization to find out how extensive the problem was and to find out just what could and should be done about it. We believe that planning, building and maintaining is not adequate and that any real systems approach to better freeways must provide for conscious, concerted operation of the freeway system. The new concept must be planning, building and operating.

The organization we set up to solve this problem in Los Angeles is appropriately enough called a Freeway Operation Group. During the past five years, this group has gone through a rapid evolutionary process. As the extent of the problem has begun to unfold, the objectives, techniques and the scope of operation of this group have continued to move through a very rapid iterative process. Rather than describe this process, we'll describe the freeway operation problem as we see it today and describe how we propose to develop an effective freeway traffic management system for Los Angeles.

FREEWAY TRAFFIC MANAGEMENT SYSTEMS

In a way, the term Freeway Traffic Management Systems is a face lift for the not-so-old term Freeway Operation Systems. However, it does embody new concepts. In addition, it (1) begins to concern itself heavily with the effective systematized coordination of the many public organizations involved in freeway operation, and (2) considers more seriously the effect of other urban transportation modes on the freeway system.

Figure 1 describes a Freeway Traffic Management System. There are two very important points to note in this description. First, that any effective Freeway Traffic Management System must consider the effect of other urban transportation modes. We must carefully determine how our urban transportation mode - the freeway - can be integrated into the urban transportation system. And just what effect other modes and other facilities not under our control should and will have on our planning and design.

A FREEWAY TRAFFIC MANAGEMENT SYSTEM:

ASSUMES:

- COMPLETION OF AN URBAN FREEWAY SYSTEM.

MUST CONSIDER:

- EFFECT OF OTHER URBAN TRANSPORTATION MODES:
  - BUSES.
  - RAIL TRANSIT.
  - EVOLVING TECHNIQUES (E.G., TRACK AIR CUSHION VEHICLE).
- EFFECTIVE UTILIZATION OF LOCAL STREETS.

SUGGESTS:

- MORE SYSTEMIZED COORDINATION BETWEEN ALL AGENCIES RESPONSIBLE FOR FREEWAY OPERATION (OR COALESCENCE OF THESE ORGANIZATIONS INTO A SINGLE FREEWAY TRAFFIC MANAGEMENT ORGANIZATION).

GENERALLY INCLUDES:

- CONTINUOUS ADJUSTMENT OF THE FREEWAY SYSTEM TO CORRECT IMBALANCES (E.G., BY INCREASING CAPACITY).
- "REAL-TIME" SURVEILLANCE.
- CENTRAL DECISION MAKING (CONTROL CENTER CONCEPT).
- CONTROL (E.G., RAMP CONTROL).
- EARLY DETECTION AND RAPID REMOVAL OF INCIDENTS.
- EFFECTIVE "REAL-TIME" INFORMATION FOR THE MOTORIST.
- SERVICE FOR STRANDED MOTORISTS.

Figure 1

Second, in most urban areas, there exists a very complex set of organizations that have responsibility for effective operation of the freeway system. In Los Angeles, these include primarily the California Division of Highways (the Freeway Operation, Traffic and Maintenance Departments) and the California Highway Patrol. Other groups involved are fire departments, ambulance services, tow facilities and so on. Each of these groups has a piece of the freeway operation "action". In certain cases, responsibilities (and actions) overlap. In other cases, there seems to be an embarrassing void (of both responsibility and action).

Future successful freeway traffic management will of necessity require very close coordination and cooperation between concerned organizations. However, because of the very size and complexity of the urban freeway system, its problems and the organizations that serve it, we believe it more likely that the authorities and responsibilities for operation of the freeway system will coalesce in future years. And will be vested in <u>one</u> organization. A single freeway traffic management organization. We realize that many firmly rooted beliefs and other complex problems will have to be overcome before that day dawns.[2]

The reason for the word "management" in the term freeway traffic management may not be obvious. However there exists an excellent analogy between the definition of management and the process we follow in the solving of freeway operation problems. One of the better definitions of management is that given by management theorists Harold Koontz and Cyril O'Donnell:

> Management is the creation of an environment in which an organized group can work effectively and efficiently toward a commonly understood goal.3/

We believe this analogy becomes clear when we define Freeway Traffic Management as:

> Creation of an environment which allows effective and efficient use of the freeway system by minimizing delay, maximizing safety and providing the motorist with a general sense of well being.

The essence of the analogy is in the planning and execution necessary to eliminate or reduce the obstacles (obstacles to either the worker or motorist). This is the creation of an effective environment.

Figure 2 shows the plan currently being developed by our Freeway Operation Department in Los Angeles. As you can see, the plan leads from an experimental stage (i.e., finding out what we can and should do) through an interim program development stage and finally to a functioning freeway traffic management system. There are several important points in the plan

FREEWAY OPERATION DEPARTMENT

GENERAL PLAN

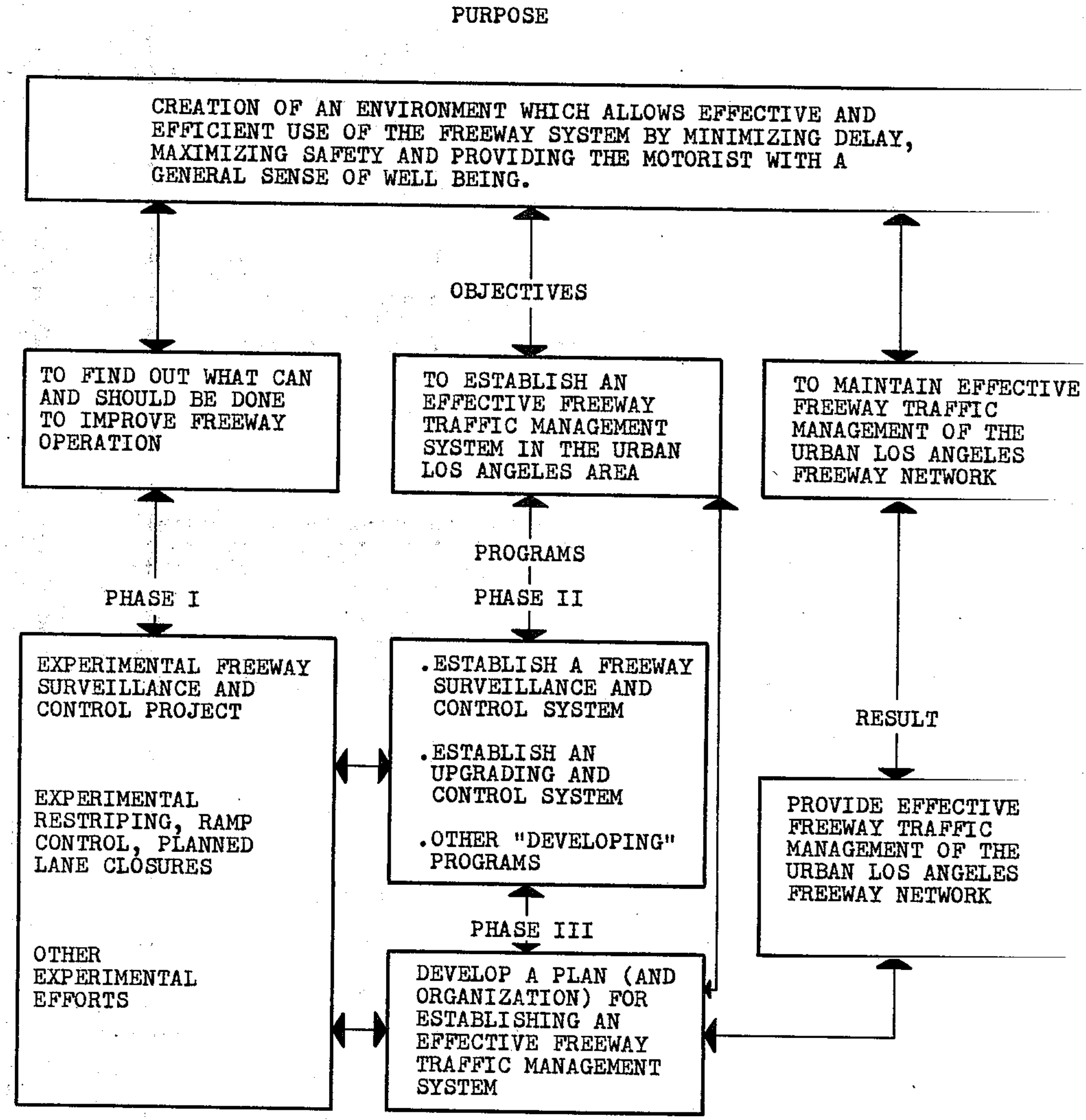


Figure 2

but one stands out and should be emphasized. We believe that before we implement a Freeway Traffic Management System over 600 miles of Los Angeles Freeways that may require an initial investment of over $100,000,000 and annual costs of $25,000,000 to $40,000,000, we must first actually know the costs and benefits of such a system. There are any number of new techniques and equipment being developed daily. And there is little doubt that most of these techniques are technically feasible (i.e., they work). But we believe it's equally important that their benefits be at least equal to their costs and that they are in a price range we can afford. This is the reason our plan begins with finding out what we can and should do (i.e., what's technically possible and what we can afford) and why we have large experimental efforts like the Los Angeles Area Freeway Surveillance and Control Project under way.

THE EXTENT OF THE LOS ANGELES AREA FREEWAY TRAFFIC PROBLEM

The Los Angeles area freeway traffic congestion problem is serious but not unsolvable. About 2.5 million motorists use these urban freeways daily for trips of various lengths. If we assume that a motorist is delayed when his speed drops below 50 mph, we can then say that these 2.5 million motorists suffer, on the average, less than two minutes in daily delay. But averages don't tell the real story. The real problem is that about 300,000 motorists suffer delays up to 30 minutes daily.

We estimate that the cost of delay from all sources in the urban Los Angeles area is about $65 million per year. And, of course, there's an additional cost for accidents caused by congestion and certainly some cost for motorist aggravation.

LOS ANGELES URBAN AREA WEEKDAY FREEWAY TRAFFIC PROBLEMS

- 2.5 MILLION MOTORISTS SUFFER LESS THAN TWO MINUTES IN DAILY DELAY.*
- PROBLEM IS THAT ABOUT 300,000 MOTORISTS SUFFER UP TO 30 MINUTES IN DELAY DAILY.
- TOTAL FREEWAY DELAY IN THE URBAN LOS ANGELES AREA FROM ALL SOURCES IS ABOUT 80,000 HOURS DAILY.
- THE FREEWAY DELAY COSTS URBAN LOS ANGELES MOTORISTS ABOUT $65 MILLION YEARLY.
- IN ADDITION, THERE ARE COSTS TO THE MOTORIST OF ACCIDENTS CAUSED BY CONGESTION AND COSTS OF MOTORIST AGGRAVATION (OR LACK OF WELL-BEING).

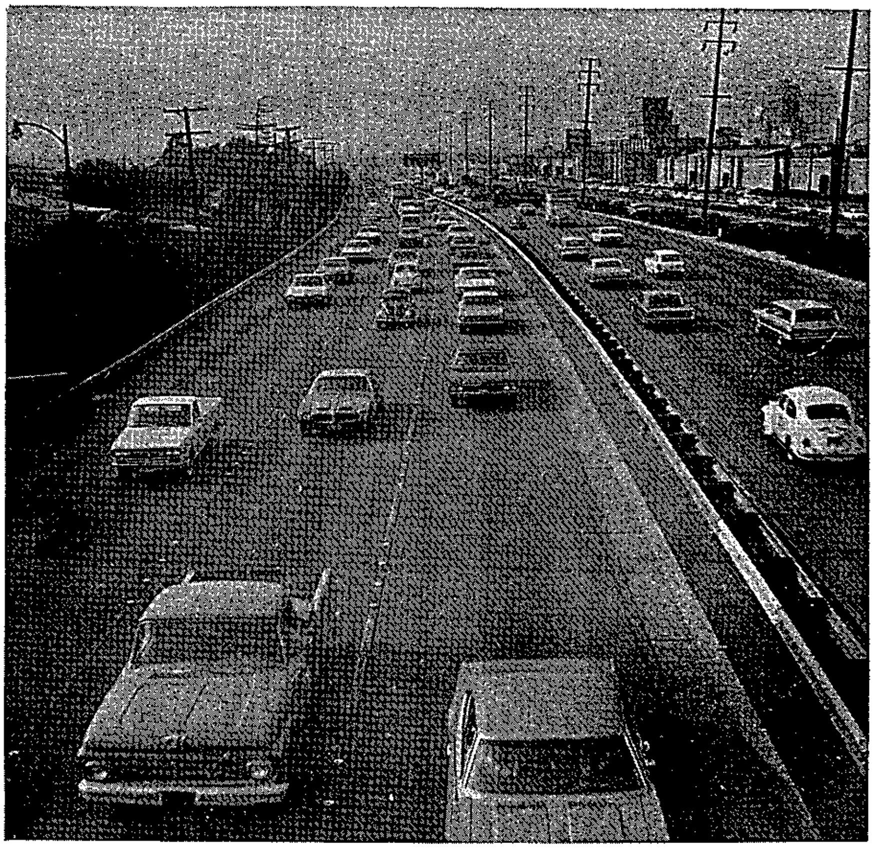
* We assume the motorist is delayed if his speed drops below 50 mph.

Figure 3

TYPES OF FREEWAY TRAFFIC CONGESTION

We're dealing with two distinct types of freeway traffic congestion. The first is that caused by critical sections that have inadvertently been designed into the system. Figure 4 shows a critical section and the resultant queue on the Santa Ana Freeway. These critical sections or bottlenecks are sections of the freeway which will not accommodate the number of motorists who would like to use them in a given period of time; therefore, some motorists must wait in line. This type of congestion occurs daily and is sometimes called recurrent congestion. Figures 5, 6, 7 and 8 show a summary of our "inventory" of this type of freeway traffic congestion in the Los Angeles area. [4/] The charts were based on a delay base of 35 mph (i.e., we believed the motorist was delayed if he was traveling at a speed less than 35 mph). As mentioned earlier, we now use 50 mph as a delay base.

The second type of freeway traffic congestion is that caused by unusual incidents. Unusual incidents can be classified as accidents, spilled truck loads, stalled cars and so on. We don't have as good an estimate of the extent of the unusual incident congestion (sometimes called nonrecurrent congestion.) But many studies across the country make us believe that these incidents may cause as much delay for the motorist as the critical



Geometric Bottleneck Congestion
Santa Ana Freeway

Figure 4

section congestion.[5/] Because of the unpredictable nature of this type congestion, it causes a disproportionate share of accidents. And because the motorist isn't able to allow time for it, incident congestion tends to be considerably more aggravating. Figure 9 shows incident congestion caused by a truck spill on the Golden State Freeway. (The photograph is from an actual helicopter/television operation.)

CRITICAL SECTION CONGESTION "SOLUTIONS"

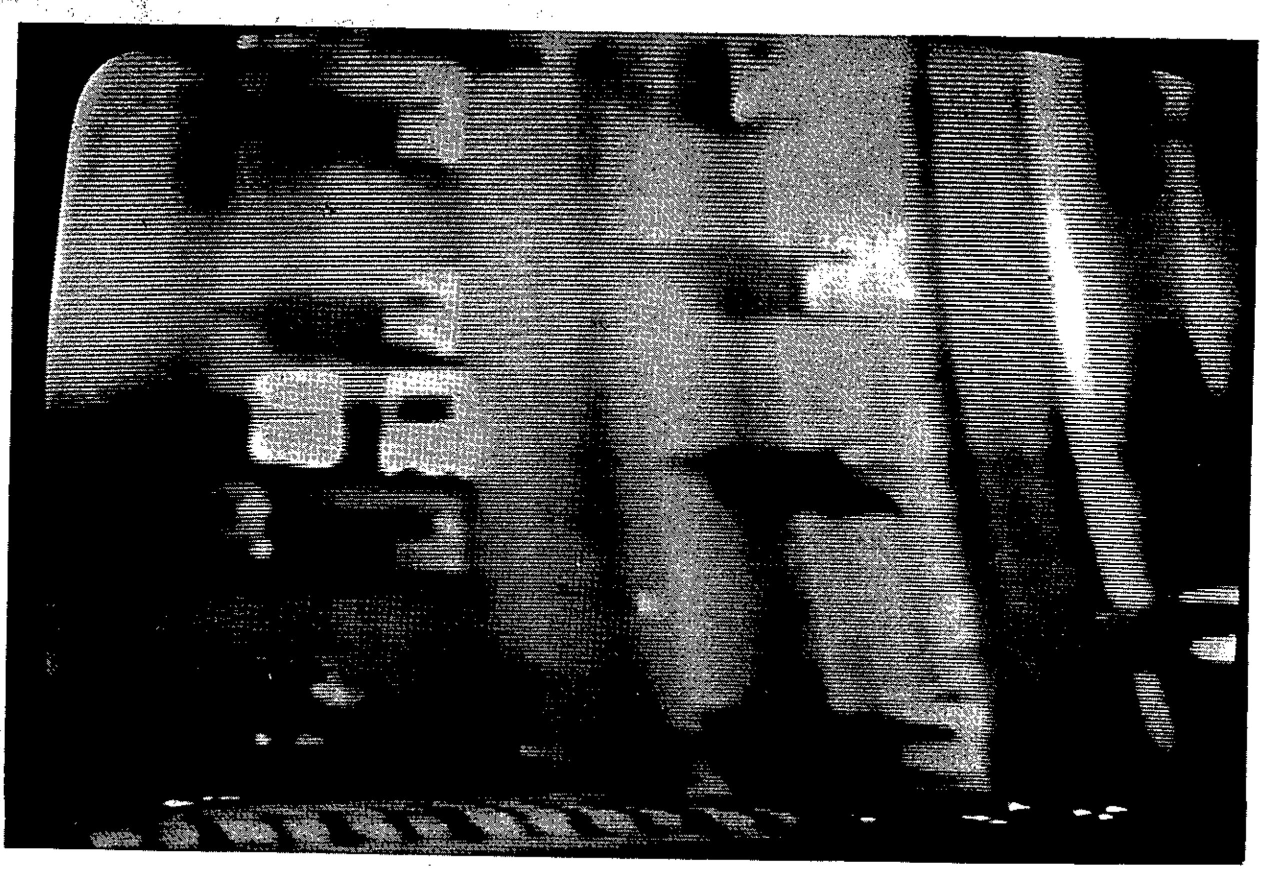
There are several available solutions to the critical section freeway congestion problem:

- Completing the proposed freeway system.
- Adding capacity.
- Limiting demand.
- Special considerations.

These solutions are not independent; rather they depend on each other.

Completing the Freeway System

Some freeways now carry a disproportionate share of the total load. Completion of other freeways will help reduce the load and will reduce the effect of some problem areas. In addition, completion of the system is required if any other approaches (e.g., upgrading, ramp control, surveillance and control) are to be successful.



Unusual Incident Congestion

Figure 9

Adding Capacity

This involves adding capacity (through restriping or physically adding lanes) in critical sections. Figure 10 shows restriping for five lanes in a critical section of the Santa Monica Freeway.

Limiting Demand

If we can't add capacity in a critical section, we can limit the number of motorists that can enter the critical section in a given time period. We do this with a technique called ramp control. This represents a temporary solution that can be used effectively until additional capacity can be provided. By the use of traffic signals on ramps entering the freeway upstream of the critical section, ramp control limits the demand to that which the section can successfully handle. Some entering traffic is then forced to use local streets to enter the freeway downstream of the critical section. Traffic enters the freeway generally one at a time at a rate predetermined by a three-dial traffic controller. Figure 11 shows a ramp queue on a new project on the inbound Hollywood Freeway. As a longer run freeway traffic management technique, ramp control provides a means of correcting imbalances created in the freeway system (e.g., changes in traffic patterns caused by changes in land use).

Figure 10 Restriping for Additional Lanes in a Critical Section on the Santa Monica Freeway

Figure 11 Ramp Control Project on the Hollywood Freeway

Special Considerations

This is a "catch-all" category that primarily contains solutions that we have so far only given some thought to. Among these are:

- Car pooling.
- Staggered Work Hours.
- Variations of the Home Work Theme.
- Exclusive Bus Ramps.

Exclusive Bus Ramps

We mention this technique first because we have actually experimented with it and find it to be very successful. In areas where we have ramp control, we provide (where possible) an exclusive lane on the ramp which allows the bus to bypass the ramp queue and enter the freeway. In all cases, the bus suffers no delay either while entering or while on the freeway. This system has also been tried successfully by the State of Texas.

It is possible that areawide ramp control (which provides a free flowing freeway) and exclusive entry for buses is superior to the exclusive bus lanes on freeways now under consideration and experimentation. Figures 12 and 13 show exclusive lanes for buses on both the Harbor and Hollywood Freeways.

Car Pooling and Staggered Work Hours

Both voluntary car pooling and staggered work hours deserve more consideration than they have been given. We are moving into studies in these areas. We, of course, expect to take full advantage of current FHWA studies.

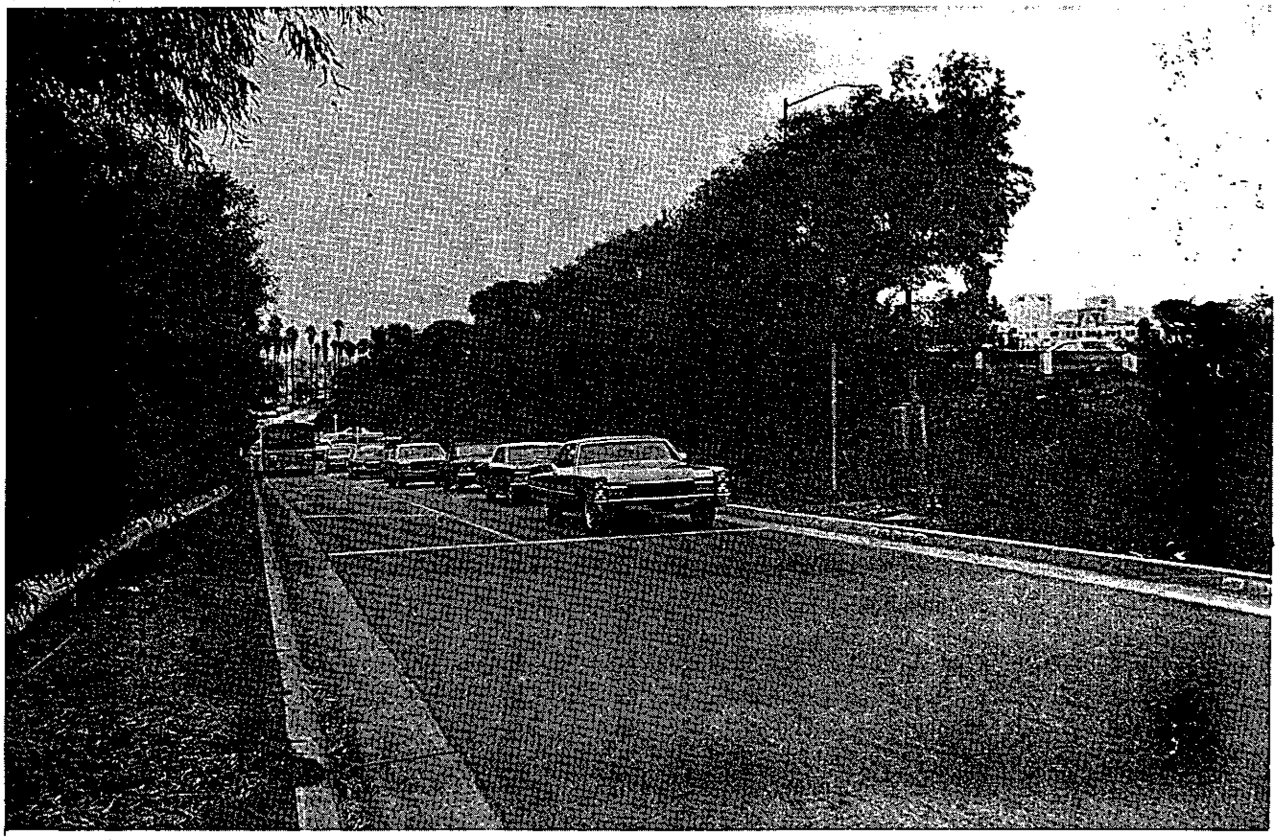


Figure 12 Exclusive Bus Entry on the Harbor Freeway

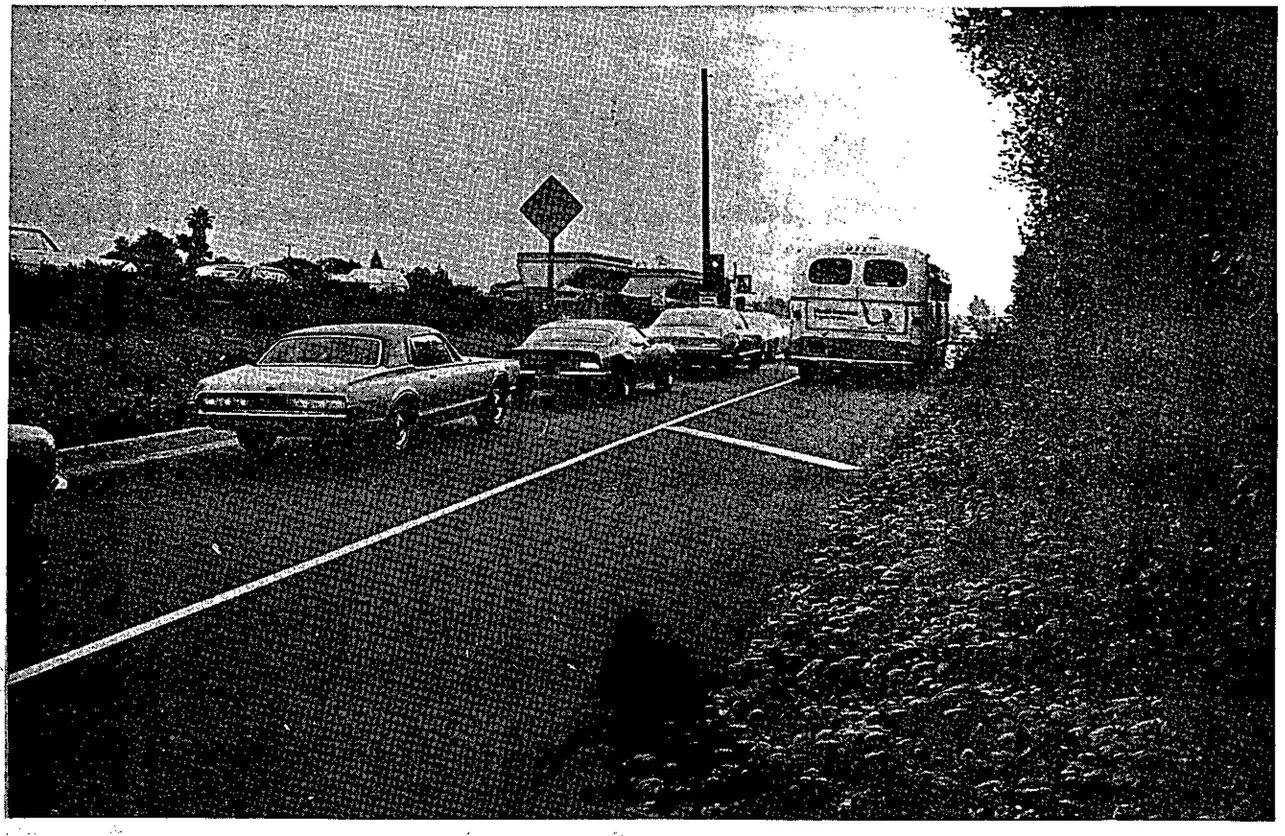


Figure 13 Exclusive Bus Entry on the Hollywood Freeway

"Home Work" Situations

The concept of home work (i.e., sending in the worker's output rather than the worker) offers some very interesting advantages in that it is one of the few positive voluntary approaches to solution of freeway congestion problems. It takes some commuters off the freeway. With the advent of more perfect communication systems, some forms of business may actually go to this form of organizational development. We have completed some preliminary studies in this area and expect to do more.

UPGRADING-CONTROL PROGRAM

We have just completed a comprehensive program for upgrading and controlling the urban freeway system in Los Angeles. The proposed program will provide Los Angeles freeway motorists with a 50 mph or greater "ride" throughout the urban Los Angeles area.* The main features of this upgrading and control system are:[6/]

- Completion of at least 30 major geometric improvements.
- Control of all on-ramps.
- Speeds of 50 mph or greater during all periods of the day.*
- Program cost: $140,000,000.

UNUSUAL INCIDENT CONGESTION "SOLUTIONS"

As with critical section congestion, many state-of-the-art techniques are available for dealing with congestion caused by

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* Except in short selected areas of the CBD.

unusual incidents. Among the most promising is a freeway surveillance and control system which may include:

- Electronic surveillance.
- Ramp control.
- Early detection and rapid removal of incidents.
- Effective "real-time" information for the motorist.
- Service for stranded motorist.

Each of these techniques can be applied without the use of the others. However, we believe that integration of these techniques within a central decision making framework has a very definite synergistic effect (i.e., the effect of the integrated system is much greater than would be the sum of the effect of individual techniques).

We have under way in Los Angeles an experimental freeway surveillance and control project. All the solutions for the unusual incident congestion just mentioned will be discussed within the framework of this project.

LOS ANGELES AREA FREEWAY SURVEILLANCE AND CONTROL PROJECT

The Los Angeles Area Freeway Surveillance and Control Project is a 42-mile experimental project that we believe will help lead the way to a comprehensive freeway traffic management system in the urban Los Angeles area within six years. A system that will eventually cover more than 600 urban freeway miles.

The freeway surveillance and control project is the largest and most comprehensive yet developed (Figure 14). It will be operated over a three-year period and will cost more than eight million dollars.

Location

The Los Angeles Area Freeway Surveillance and Control Project is located in the heart of the urban Los Angeles area on three of the most heavily traveled freeways in the world: the Santa Monica, San Diego and Harbor Freeways. The project is 42 miles in length and has within or near its boundaries 56 freeway interchanges, a portion of downtown Los Angeles, USC, UCLA and Los Angeles International Airport (Figure 15).

Purpose

The Los Angeles Area Freeway Surveillance and Control Project has two objectives. The first is to test and evaluate various techniques for improving freeway operation. The second is to integrate those techniques showing greatest promise into an effective centrally controlled system.

The Electronic Surveillance System

The initial surveillance system will provide the necessary instrumentation and communication equipment required for testing of the techniques mentioned. The surveillance project will also gather the data necessary for evaluation of the techniques.

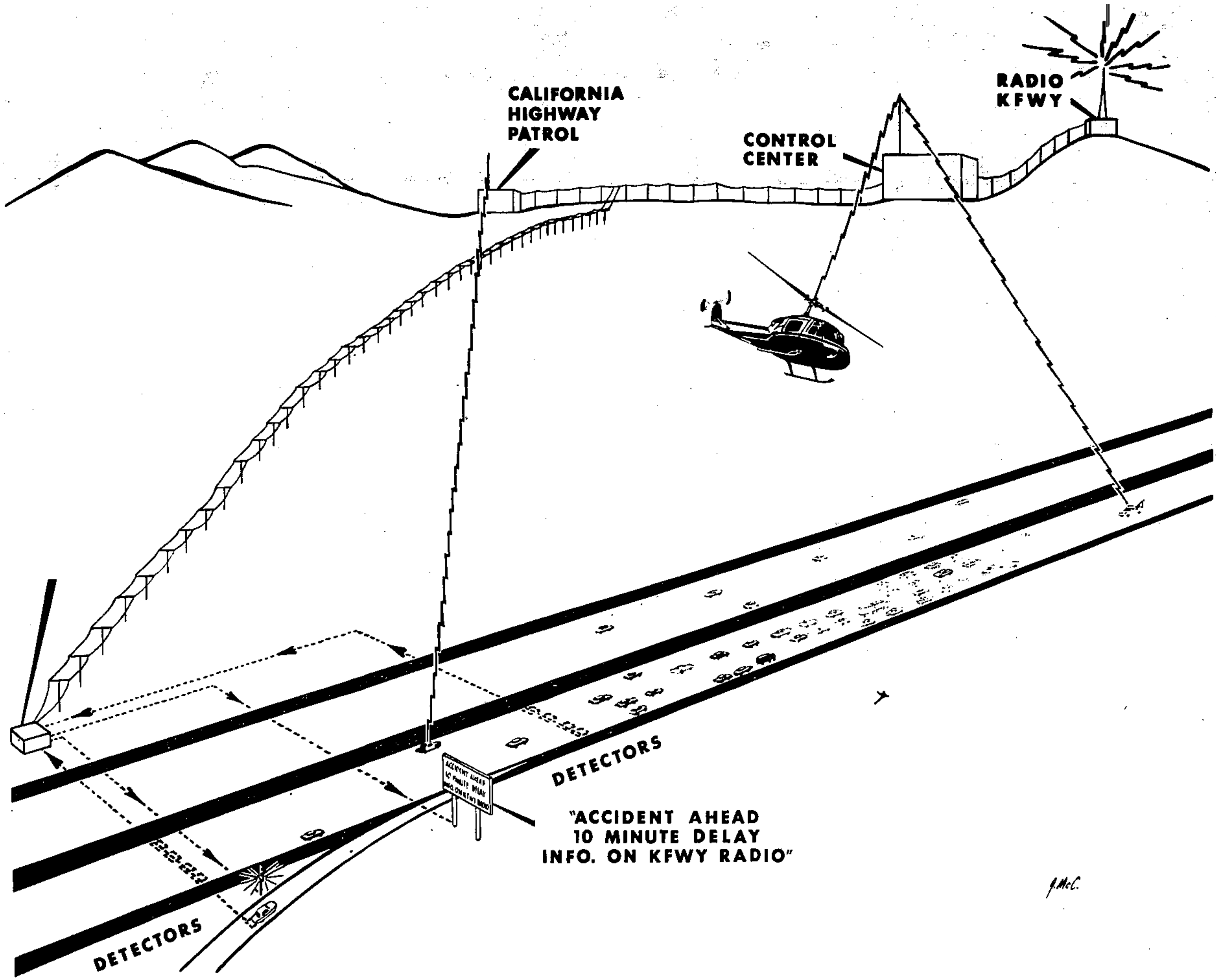
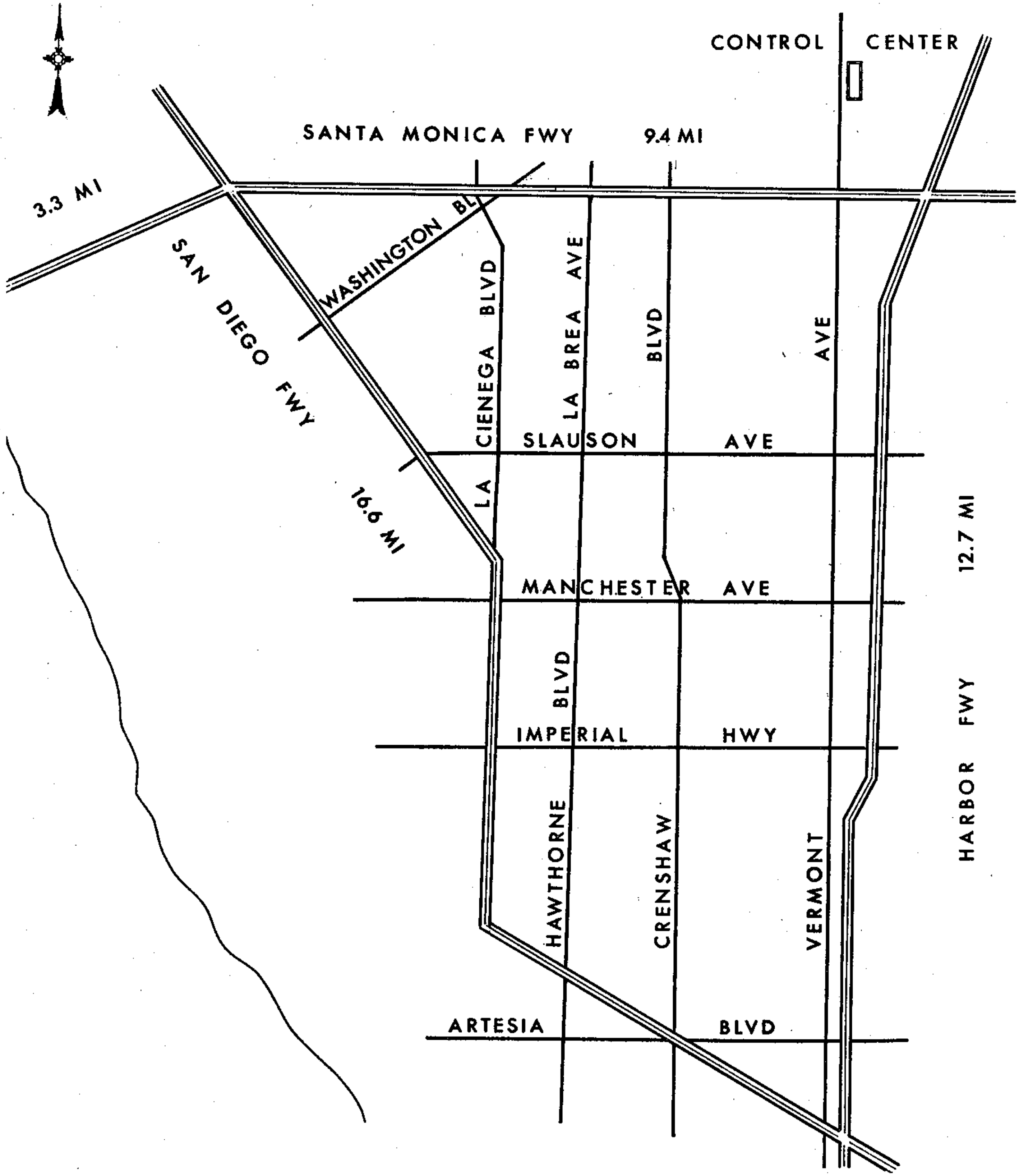


Figure 14 Artist's Concept of the LAAFSCP in Action



Los Angeles Area Freeway Surveillance and Control Project

Figure 15

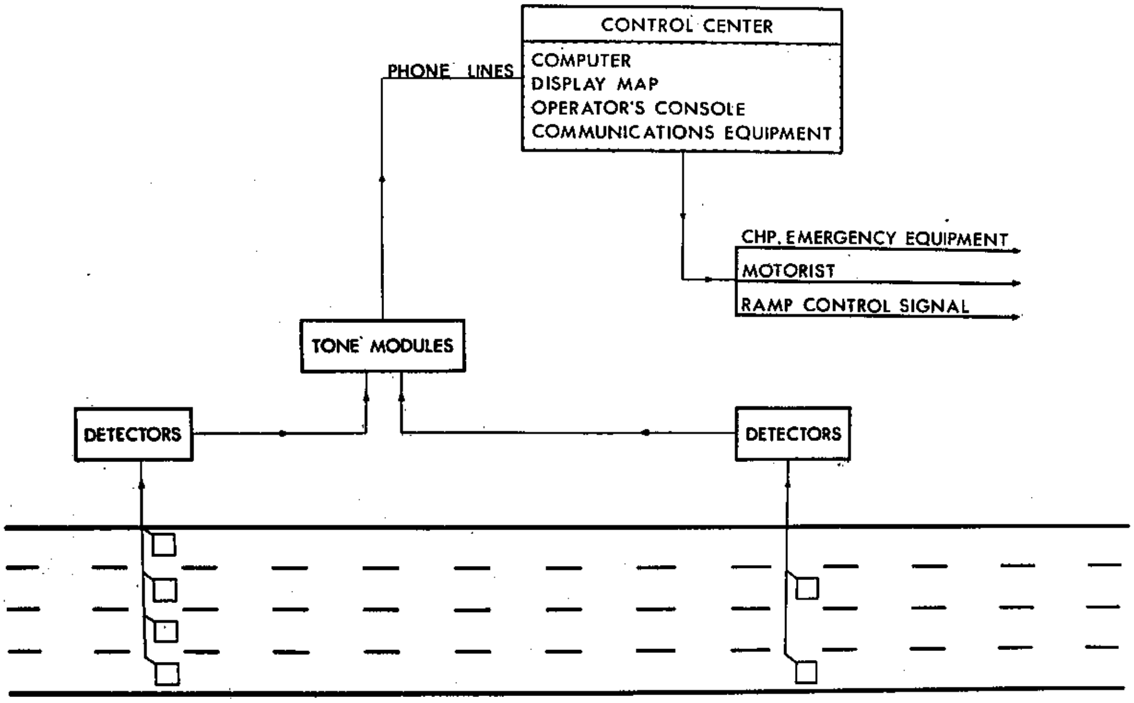
The electronic surveillance system will be composed of (Figure 16) (1) a series of more than 700 traffic sensors located in the freeway at one-half mile intervals, (2) detectors and telemetering equipment that will transmit traffic data over telephone lines to (3) a control center (Figure 17). The control center will have (1) a digital computer to log incoming data and to help make "decisions", (2) a display or status map of the surveillance project showing the status of traffic on the freeway at all times, (3) other display equipment including status lights for all metered ramps, computer output devices, a television screen, and (4) necessary communication equipment. The control center will be operated by an interdisciplinary team composed of traffic engineers, trained maintenance people and highway patrol officers.

TECHNIQUES TO BE TESTED AND EVALUATED

At the present time, we can see many techniques well within the state-of-the-art that could contribute to better freeway operation. They fall within four general categories:

1. "Traffic Sensitive" Ramp Control

The California Division of Highways has three successful ramp control projects in operation in the Los Angeles area. All are simple "fixed time" systems that meter traffic onto the freeway using historical data (i.e., they meter traffic



BASIC SURVEILLANCE PROCESS

Figure 16

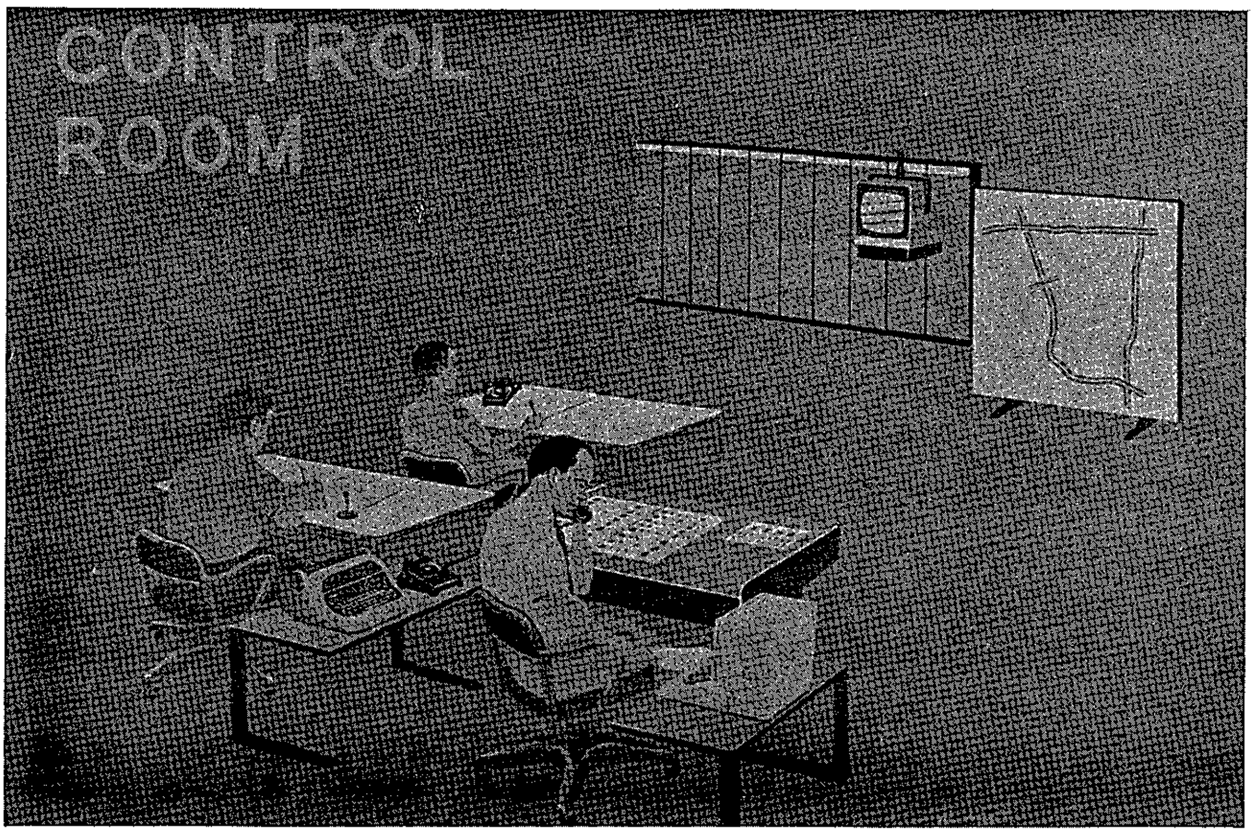


Figure 17

onto the freeway based on what the condition of the freeway should be at that time). An evaluation of this "fixed time" ramp control has already been made. During the course of the surveillance and control project, several ramp control projects (existing and proposed) within the limits of the project will be made traffic sensitive and will be controlled by our computer. A determination will be made of the marginal benefits of traffic sensitive centralized computer control.

2. Early Detection and Rapid Removal of Unusual Incidents

The early location and rapid removal of freeway incidents remains one of the most promising areas for possible freeway operation improvement. Techniques to be evaluated in this area are (1) a computer logic for rapidly detecting "unusual" incidents, (2) the use of aircraft surveillance and "live" closed circuit television transmission from an aircraft (Figure 18) and (3) the use of specially equipped state-owned tow trucks to remove "unusual" incidents completely from the freeway (Figure 19).

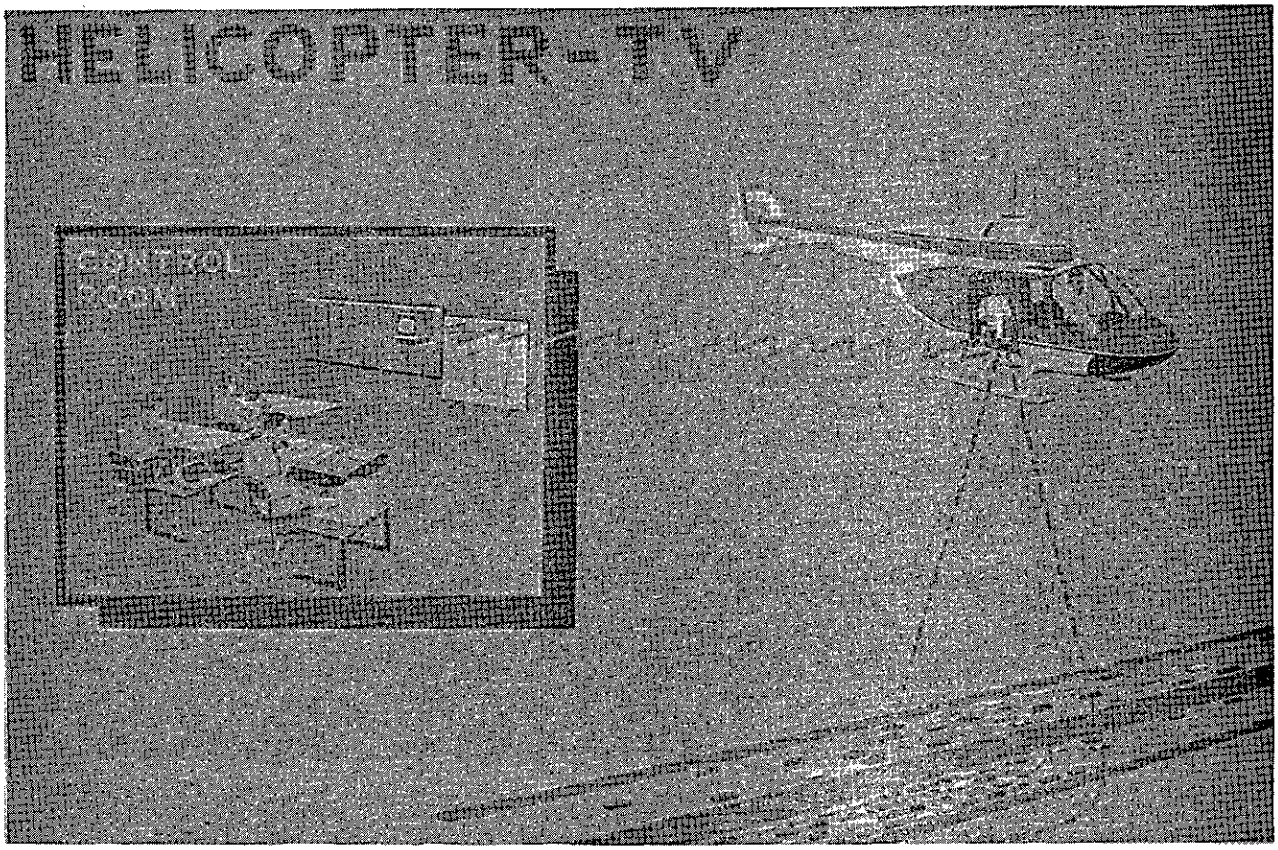
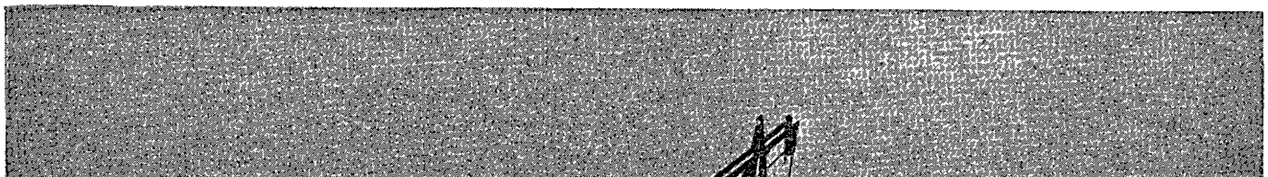


Figure 18



3. <u>Effective Warning and Information for the Motorist</u>

Although in most cases, we provide the freeway motorist with excellent signing, we do little to provide him with information on day-to-day (i.e., "real time" information) freeway happenings. In this general area, the techniques to be tested and evaluated are (1) improvement of commercial radio traffic advisories, (2) roadside radio (Figure 20), and (3) freeway-size changeable message signs (Figure 21).

We believe each of these communication modes offers unique benefits and that the right combination of the three will provide a very effective system.

4. <u>Service for the Stranded Motorist</u>

In the urban Los Angeles area, we now have over 2,000 freeway phones that have been installed by the County of Los Angeles. The County also pays the phone bills. We have been asked many times to accept the costs of this system. We have so far denied these requests because we believe there are other means that may be able to provide the stranded motorist with better service at less cost. As a part of our surveillance project, we are now evaluating the freeway phone system and will soon be evaluating other means of providing service for stranded motorists. One technique that we will be looking at is the service patrol. (Figures 22 and 23.)

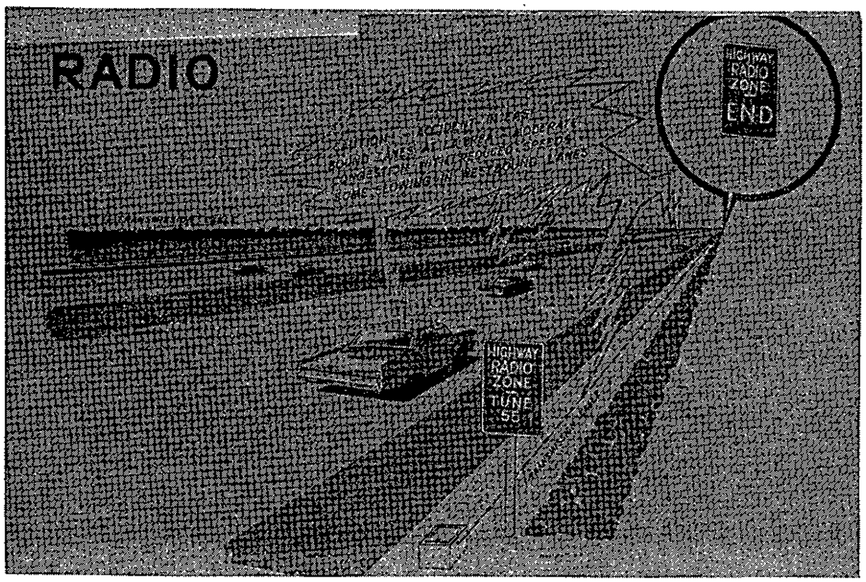


Figure 20

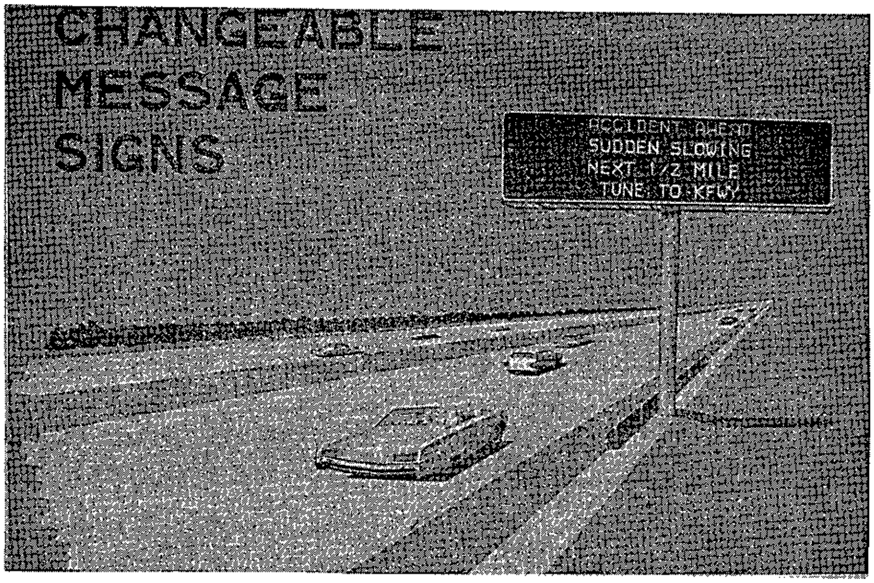


Figure 21

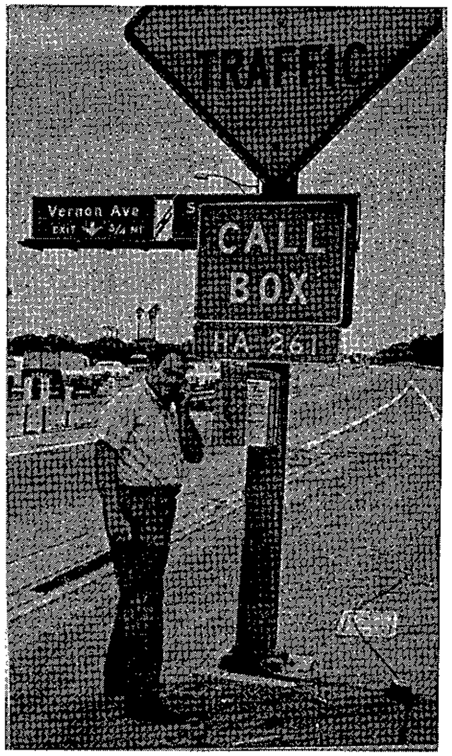
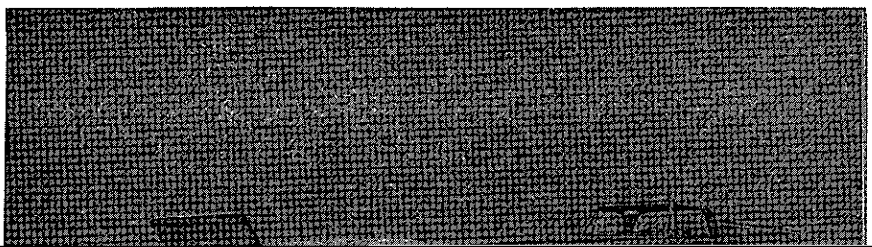


Figure 22



In addition to developing the best system for servicing the stranded motorist, we're going to determine who should provide the service. For example, on the San Diego Freeway system, this service is provided by a private organization (the American Oil Company) at no cost to the State or the motorists serviced.

Time Frame for the Project

The electronic surveillance system is now under construction in Los Angeles. Completion is expected in the summer of 1971. At that time, the helicopter/television system, tow trucks and other equipment mentioned will begin to function. Completion of the project is expected in 1973.

A FREEWAY TRAFFIC MANAGEMENT SYSTEM FOR LOS ANGELES

We mentioned earlier that we expected to have a functioning freeway traffic management system in Los Angeles in six years. And we do. We feel a great urgency. We believe that rapid, forceful action is required if the freeway system is to retain its position in the urban transportation system. For this reason, we have begun design on an urban freeway traffic management system for Los Angeles even before the results of our experimental efforts are in. This approach will require changes in design as experimental results come in. But it assures us of the most rapid development of an effective freeway traffic management system.

<u>FREEWAY TRAFFIC MANAGEMENT: A NEW AND IMPORTANT STEP IN THE SOLUTION TO THE URBAN TRANSPORTATION CRISIS</u>

We'd like to reemphasize the importance of the Freeway Traffic Management concept. In these days within urban areas, we tend to see an either/or approach to the urban transportation crisis. Some people are saying that as an urban transportation mode, the freeway is obsolete. They couldn't be further wrong. But there must be greater emphasis on full utilization of the freeway system. As mentioned earlier, we <u>must</u> provide for conscious, concerted operation of the urban freeway system. Our concept must be planning, building and <u>operating</u>.

We sincerely believe that <u>if</u> the urban freeway system is completed as planned, <u>if</u> deficiencies can be removed from the system through proper upgrading and <u>if</u> an effective freeway traffic management system can be implemented, that the urban freeway system will continue to retain its place as a viable and major part of any future urban transportation system.

REFERENCES

1. Rep. John Blatnik, Congressional Hearing, July 20, 1967.

2. John West, The Los Angeles Area Freeway Surveillance and Control Project: A Complete Systems Description, unpublished California Division of Highways internal report, June 1969.

3. Harold Koontz and Cyril O'Donnell, Principles of Management, McGraw-Hill, New York, 1964, p. 38.

4. Rol Marino, Geometric Bottleneck Congestion Inventory: First Interim Report, California Division of Highways, February 1970.

5. Primarily studies on the Illinois Division of Highways Chicago Area Expressway Surveillance Project, Chicago, Illinois.

6. Richard Murphy, A Program to Upgrade and Control the Los Angeles Freeway Network, unpublished California Division of Highways internal report, July 1970.

California Makes Its Move

by John West

Next summer in a brightly lighted control center in downtown Los Angeles, traffic data from 42 miles of urban Los Angeles freeways will begin to pour into a computer. Visual displays controlled by the computer will be closely watched by a highly trained team. The initial operation of this control center will signal California's move into the field of "real-time" freeway traffic management.

California's concern with freeway traffic congestion began in earnest with formation of a group to study the problem in 1965. The evolution of programs developed by that group was described in "A New Look in Freeway Operation" (August 1969, TRAFFIC ENGINEERING). This article describes a major experimental effort in the area of "real-time" freeway traffic management.

the problem

The Los Angeles urban area freeway traffic problem is serious but not unsolvable. About 2.5 million motorists use the urban freeway system daily, and nearly 500,000 of these are regular commuters. Assuming the motorist is delayed when his speed drops below 50 mph, on the average these 2.5 million motorists suffer less than two minutes in daily delay. Unfortunately, averages don't tell the real story. The real problem is that some 300,000 motorists suffer delays up to 30 minutes daily.

Estimates put the cost of freeway delay from all sources in the urban Los Angeles area at about $65 million per year, with additional cost for accidents caused by congestion, not to mention the unmeasurable cost of motorist aggravation.

types of congestion

There are, in this case, two distinct types of freeway traffic congestion. The first is that caused by critical sections that have inadvertently been designed into the system (that is, land use patterns have changed). These critical sections or bottlenecks are sections of the freeway which won't accommodate the number of motorists who would like to use them in a given period of time; therefore, some motorists must wait in line. This type of congestion occurs daily and is sometimes called recurrent congestion.

The second type of freeway traffic congestion is that caused by unusual incidents. Unusual incidents can be classified as accidents, spilled truck loads, stalled cars and so on. Good estimates of the extent of the unusual incident congestion (sometimes called nonrecurrent congestion) are not available, but many studies across the country indicate that these incidents may cause as much delay for the motorist as the critical section congestion. Because of the unpredictable nature of this type congestion, it causes a disproportionate share of accidents, and because the motorist isn't able to allow time for it, incident congestion tends to be considerably more aggravating.

critical section congestion "solutions"

There are several available solutions to the critical section freeway congestion problem:

- Completing the proposed freeway system.
- Adding capacity.
- Limiting demand (e.g., ramp control).
- Special considerations (e.g., car pooling, staggered work hours, exclusive bus entry onto freeways, home work organization).

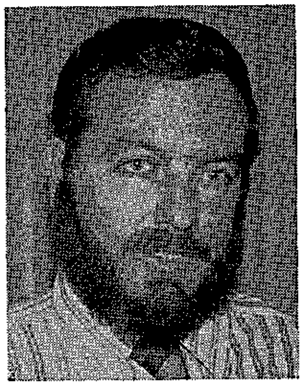
There is presently a major program in the Los Angeles area aimed at eliminating this type of congestion. The main features of this upgrading and control program are:

- Completion of at least 30 major geometric improvements.
- Control of all on-ramps.
- Speeds of 50 mph or greater during all periods of the day (except in short areas of the CBD).
- Program cost: $115,000,000.
- Program to be completed over a 6-10 year period.

unusual incident congestion "solutions"

As with critical section congestion, many state-of-the-art techniques are available for dealing with congestion caused by unusual incidents. Among the most promising is a freeway surveillance and control system which may include electronic surveillance, ramp control, early detection and rapid removal of incidents, effective "real-time" information for the motorist, and service for the stranded motorist.

The freeway surveillance and control concept moves California into the area of "real-



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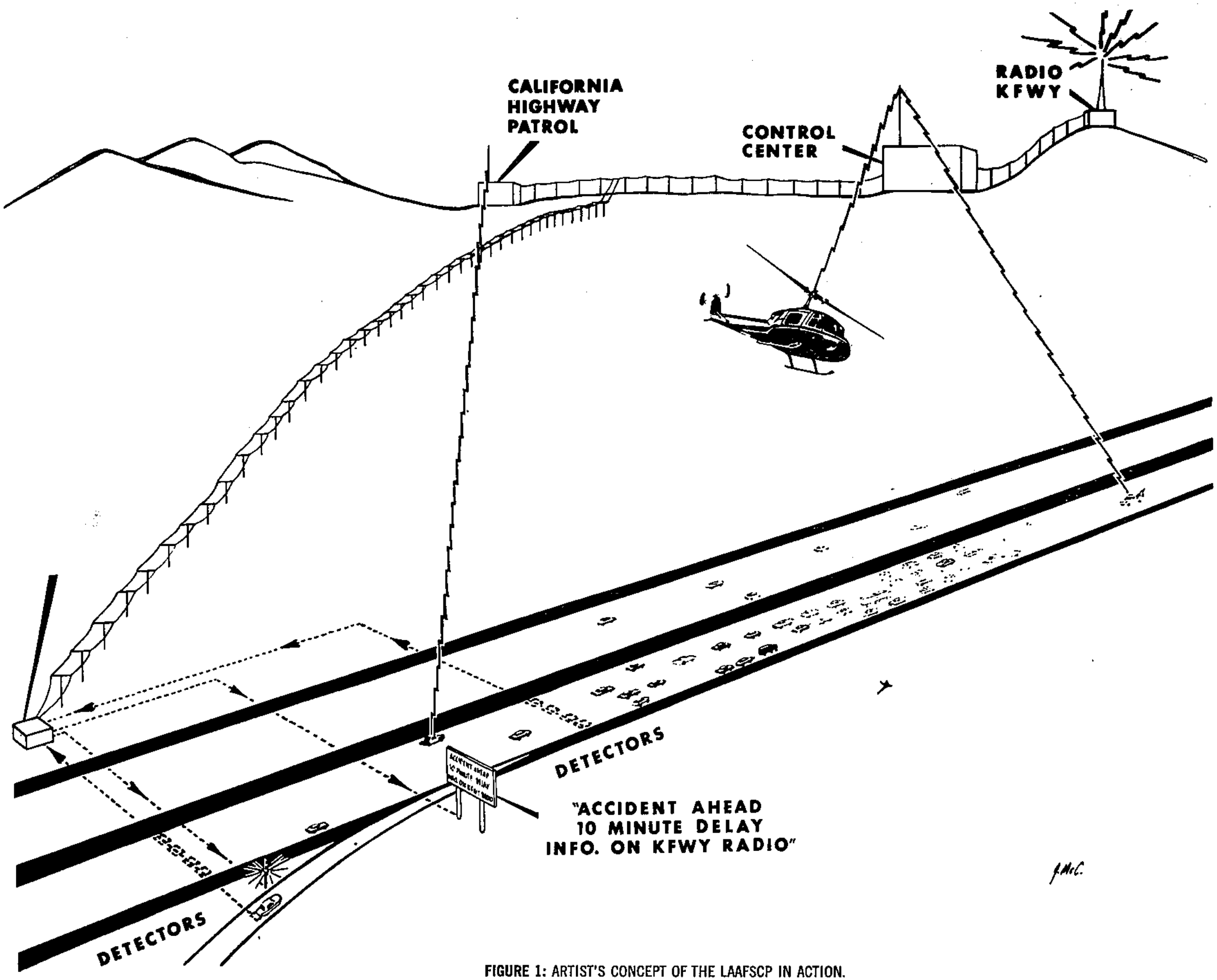


FIGURE 1: ARTIST'S CONCEPT OF THE LAAFSCP IN ACTION.

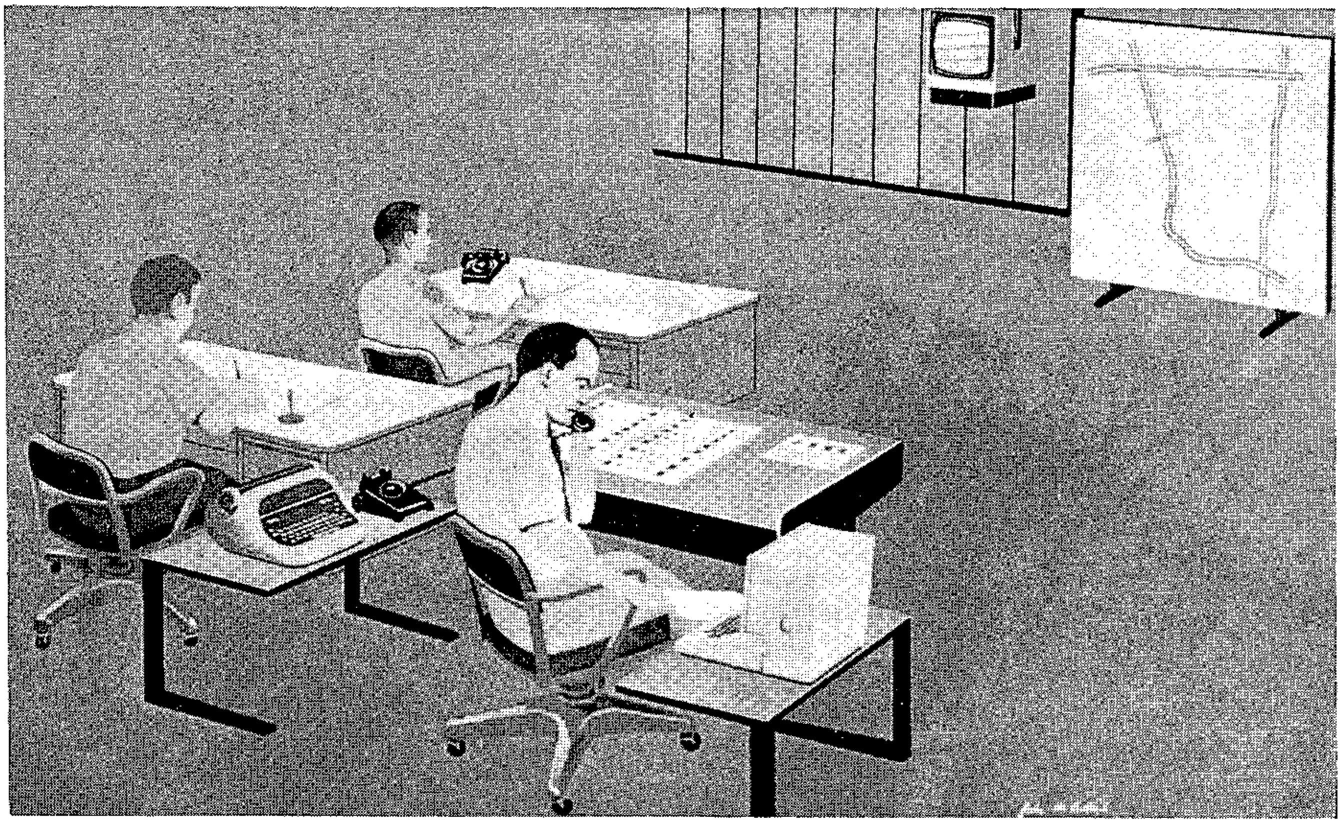


FIGURE 2: CONTROL CENTER.

time" freeway traffic management. Each of these techniques can be applied without the use of the others. However, integration of these techniques within a central decision making framework has a very definite synergistic effect (i.e., the effect of the integrated system is much greater than would be the sum of the effect of individual techniques).

the Los Angeles project

The Los Angeles Area Freeway Surveillance and Control Project is a 42-mile experimental project that will help lead the way to a comprehensive "real-time" freeway traffic management system in the urban Los Angeles area within six years. The system will eventually cover more than 600 urban freeway miles.

The project is the largest and most comprehensive of its nature yet developed (Figure 1), and will be operated over a three-year period at a cost of more than $8 million.

location

The Los Angeles Area Freeway Surveillance and Control Project is located in the heart of the urban Los Angeles area on three of the most heavily traveled freeways in the world: The Santa Monica, San Diego and Harbor Freeways. The project is 42 miles in length and has within or near its boundaries 56 freeway interchanges, a portion of downtown Los Angeles, USC, UCLA and Los Angeles International Airport.

The Project has two objectives, the first of which is to test and evaluate various techniques for improving freeway operation. The second is to integrate those techniques showing greatest promise into an effective centrally controlled system.

electronic surveillance system

The initial surveillance system will provide the necessary instrumentation and communication equipment required for testing of the techniques and will gather the data necessary for evaluation of the techniques.

This system will be composed of a series of more than 700 traffic sensors located in the freeway at one-half mile intervals and detectors and telemetering equipment that will transmit traffic data over telephone lines to a control center (Figure 2). The control center will have a digital computer to log incoming data and to help make "decisions," a display or status map of the surveillance project showing the status of traffic on the freeway at all times, display equipment including status lights for all metered ramps, computer output devices, a television screen, and necessary communication equipment. It will be operated by an interdisciplinary team composed of traffic engineers, maintenance people and highway patrol officers.

The freeway traffic sensor/detectors provide traffic data in the form of traffic volume and occupancy. Occupancy is a measure of "how occupied" the freeway is and can be compared to density. This data is fed into the computer and turned into information, much of the information, for the "in-time" decisions, appears in the form of visual displays.

We can see many techniques well within the state-of-the-art that could contribute to better freeway operation. They fall within four general categories.

• "Traffic Sensitive" Ramp Control: The California Division of Highways has three successful ramp control projects in operation in the Los Angeles area (Figure 3). All are simple "fixed time" systems that meter traffic onto the freeway based on what the condition of the freeway should be at that time. An evaluation of this "fixed time" ramp control has already been made. During the course of the surveillance and control project, several ramp control projects (existing and proposed) within the limits of the project will be made traffic sensitive and will be controlled by computer. A determination will be made of the marginal benefits of traffic sensitive centralized computer control.

The traffic sensitive ramps will be in an "on-line" mode with rates selected by the computer. A manual over-ride is also provided.

• Early Detection and Rapid Removal of Unusual Incidents: The early location and rapid removal of freeway incidents remains one of the most promising areas for possible freeway operation improvement. Techniques to be evaluated in this area are: A computer logic for rapidly detecting "unusual" incidents; the use of aircraft surveillance and "live" closed circuit television transmission from an aircraft; and the use of specially equipped state-owned tow trucks to remove "unusual" incidents completely from the freeway.

The computer "logic" is a special computer program that provides an alarm for the control center team and will be described later in the article. The helicopter/television system is intended to provide additional information as required for control team decisions.

• Effective Warning and Information for the Motorist: Although in most cases freeway signing is excellent, little information on day-to-day freeway happenings ("real-time" information) is provided. In this area, the techniques to be tested and evaluated are the improvement of commercial radio traffic advisories, roadside radio (Figure 4), and freeway-size changeable message signs (Figure 5).

Each of these communication modes offers unique benefits and the right combination of the three can provide a very effective system.

The collection of this information from many sources and its output to the motorist through audio or visual means is a complex process that requires integration of "on-line" and "in-time" techniques.

• Service for the Stranded Motorist: As part of the surveillance project, the existing urban freeway phone system will be evaluated along with other means of providing service for stranded motorists, including the service patrol (Figure 6).

time frame

The electronic surveillance system is now under construction in Los Angeles with

FIGURE 3: RAMP CONTROL ON THE HARBOR FREEWAY.

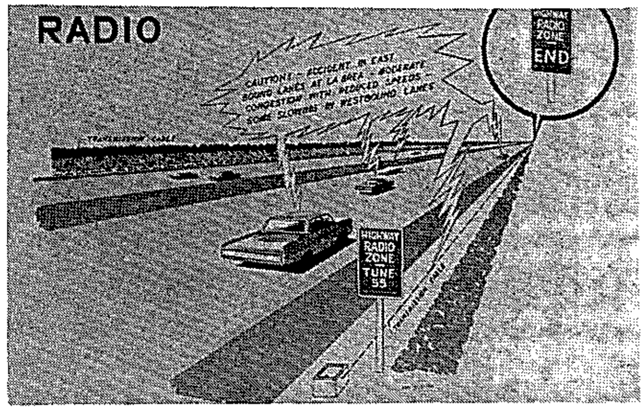


FIGURE 4: ROADSIDE RADIO.

FIGURE 5: CHANGEABLE MESSAGE SIGNS.

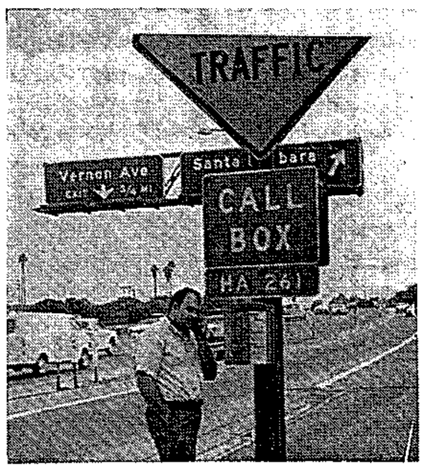
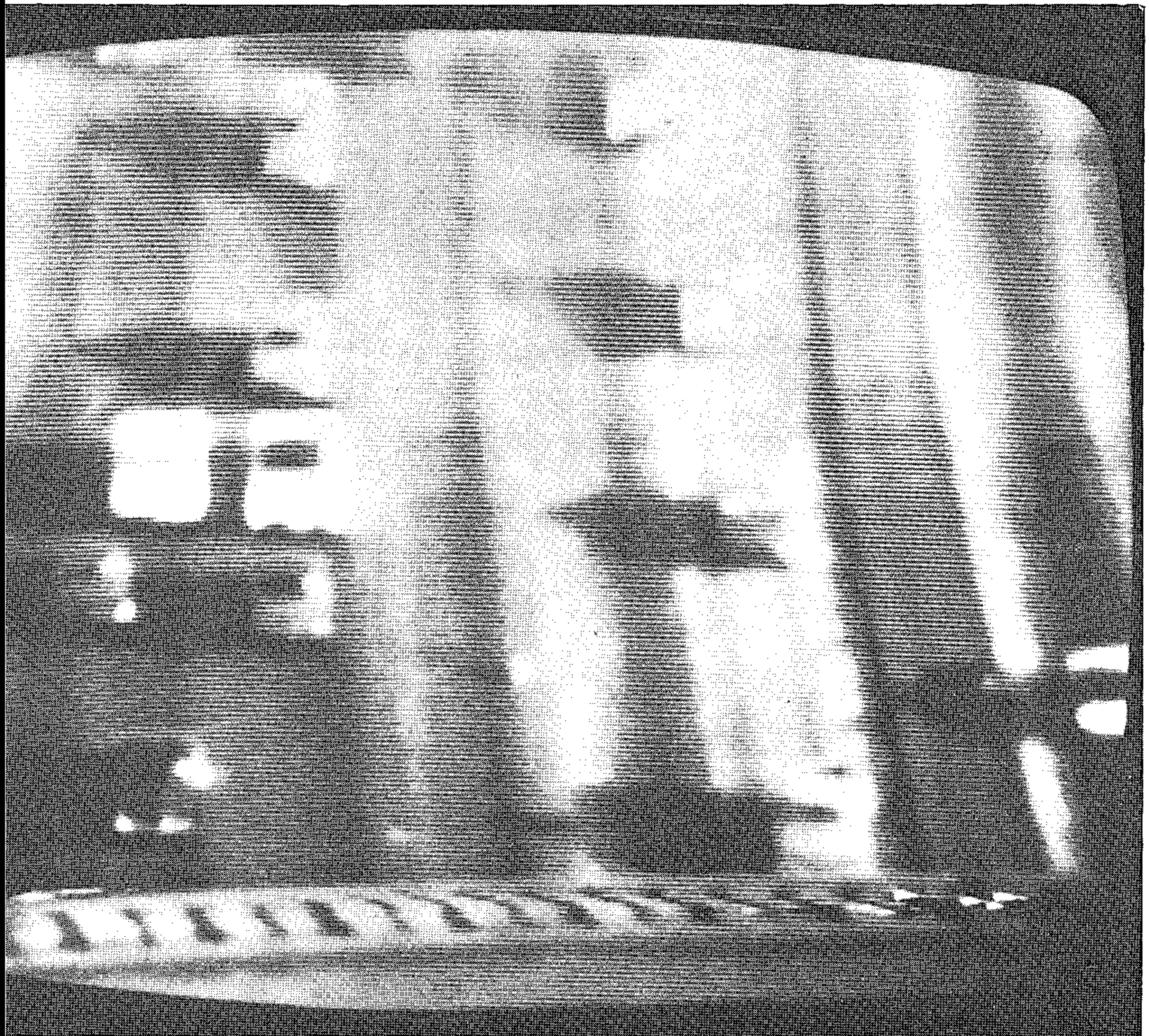


FIGURE 6: FREEWAY PHONES.

OF TRUCK SPILL ON THE GOLDEN STATE FREEWAY.



completion expected in the summer of 1971. At that time, the helicopter/television system, tow trucks and other equipment will begin to function. Completion of the project is expected in 1973.

"real-time" decisions: an example

A truck spill on the Golden State Freeway (Figure 7) provides an example of how traffic data and freeway operation techniques are combined within a "real-time" centralized decision making framework in an effective traffic management system.

The truck spill was a large box of glassware of some type which settled in the second lane from the median and, in the process, scattered glass over both this lane and the median lane. Traffic diverted around the spill by using the two right lanes of the freeway and the median. Once the box hit the pavement and scattered its contents, the "real-time" traffic management system process that would have occurred is as follows.

detection of the incident

The computer is provided with an incident detection logic (computer program) that allows it to detect unusual incidents that affect traffic movement on the freeway. The incident logic functions even though the incident may have occurred on an already congested section of freeway.

Figure 8 shows the effect of the truck spill. The incident computer program requires the computer to scan each sensor/detector 30 times per second and constantly compares the upstream and downstream occupancy of adjacent detector stations. The computer updates occupancy values every 20 seconds for a one-minute running total, so the comparison between stations is for a one-minute period. The actual comparison is the ratio of downstream occupancy to upstream occupancy. When an incident blocking some portion of the freeway occurs, the occupancy level downstream of the incident goes down and the occupancy level upstream goes up.

The computer calculates the percent difference in occupancy between adjacent detector stations with respect to the upstream detector station at the end of each sampling time period. When this percent difference is greater than, for example, 55 percent, a bottleneck condition exists. In this case, the computer calculates the relative percentage change between the present occupancy value and the occupancy value of the preceding sample for the downstream detector station. In a normal bottleneck, this downstream occupancy should remain essentially constant; however, if an incident blocks the roadway, the downstream occupancy will rapidly decrease when compared to the occupancy of the previous sampling time period at that station.

operator alarm

When the relative percentage change between the occupancy values of the downstream station exceeds a certain value, the computer signals the operator by flashing a red light on his console telling him which part of the status map to look at, and flashing a red light at the location of the incident on the status map. The flashing lights also alert the other members of the control center team. At this point, the team only knows that an incident has occurred and its location.

computer display

The operator seeks additional information from the computer through a CRT display. What he sees is a display showing seven sensor/detector stations, three or four on either side of the incident, which gives "real-time" traffic data (volumes and occupancies) for each sensor/detector station (Figure 9). This data is updated every 20 seconds. The display also tells the operator the one-minute data totals for the past five minutes. Although the display tells the operator that either one or two lanes are blocked, he can't tell which because of the diversion to the median.

decision point one

While the operator has been scanning the CRT, information may have come in from other sources (e.g., California Highway Patrols, California Highway Patrol switchboards that handle freeway phones, Division of Highways maintenance trucks, etc.). At this point, the control center team makes the first decision. The elapsed time from the moment the box hit the pavement until the decision has been made is two to three minutes. The decisions to be made include what equipment should be dispatched, whether additional information is required (e.g., helicopter/television coverage), what equipment should be alerted pending further information, and what information should be sent to the motorist.

In this case, the following decisions would be made: (1) Dispatch California Highway Patrol vehicles and a tow truck, (2) ask for helicopter/television coverage, (3) provide no information to commercial radio stations, and (4) provide alerts to motorists upstream of the incident through roadside radio and/or changeable message signs.

Decisions are based on the apparent seriousness of the incident and the availability of equipment.

helicopter/television coverage

The helicopter that will be used in the project is capable of being less than ten minutes from any point on the surveillance project. This system will provide both voice and live video transmissions of the incident scene to the control center. The video is microwaved. The helicopter contains an on-board taping system so that if a multi-story building should affect the microwave, the scene can be taped. The helicopter will then be able to gain altitude and send an "instant replay" to the control center which can receive a great deal of information from the overhead picture.

decision point two

After the additional information is received from the helicopter/television, decision point two is reached. The sequence and types of decisions are the same as those made at decision point one except that more information is now available.

In the example no additional equipment would have been dispatched since the tow truck operator would have been able to sweep up the glass; information on the incident and its expected duration would have been provided to commercial radio stations; and roadside radio and/or changeable message signs would have been providing alerts to motorists approaching upstream of the incident queue and general information on the incident and its duration upstream of and in the incident queue.

decision point three

The control center will continue to monitor the incident and will provide an alert when the incident has been cleared up and traffic is moving normally.

importance of the system

For years, highway organizations have followed a concept of planning, building and maintaining freeways. Most operational considerations have been confined to signing and ad hoc maintenance cleanup. There has been no conscious concern for the "real-time" concerns of the motorist. The concern has rather been after the fact.

The Freeway Traffic Management concept is important and must be further developed, because if effective "real-time" freeway traffic management systems can be developed and implemented, the urban freeway system will continue to retain its part as a viable and major part of any future urban transportation system.

TIME	SD14N OC VOL	SD15N OC VOL	SD16N OC VOL	SD17N OC VOL	SD18N OC VOL
1801	21 047	17 053	23 118	20 061	22 122
1802	20 050	18 055	20 123	21 063	18 113
1803	22 045	16 050	22 076	19 052	20 118
1804	21 044	23 038	44 080	09 039	19 082
1805	24 030	42 035	59 072	10 036	09 079
180520	40 012	53 014	58 022	11 012	10 025

	SD14S OC VOL	SD15S OC VOL	SD16S OC VOL	SD17S OC VOL	SD18S OC VOL
1801	09 082	11 041	10 081	10 042	09 080
1802	10 080	10 039	11 084	12 038	10 083
1803	11 079	10 040	10 083	18 039	09 081
1804	10 073	08 035	09 074	25 036	18 075
1805	12 072	09 034	10 072	27 034	25 073
180520	11 023	10 012	10 024	28 011	24 025

FIGURE 9: CRT DISPLAY.

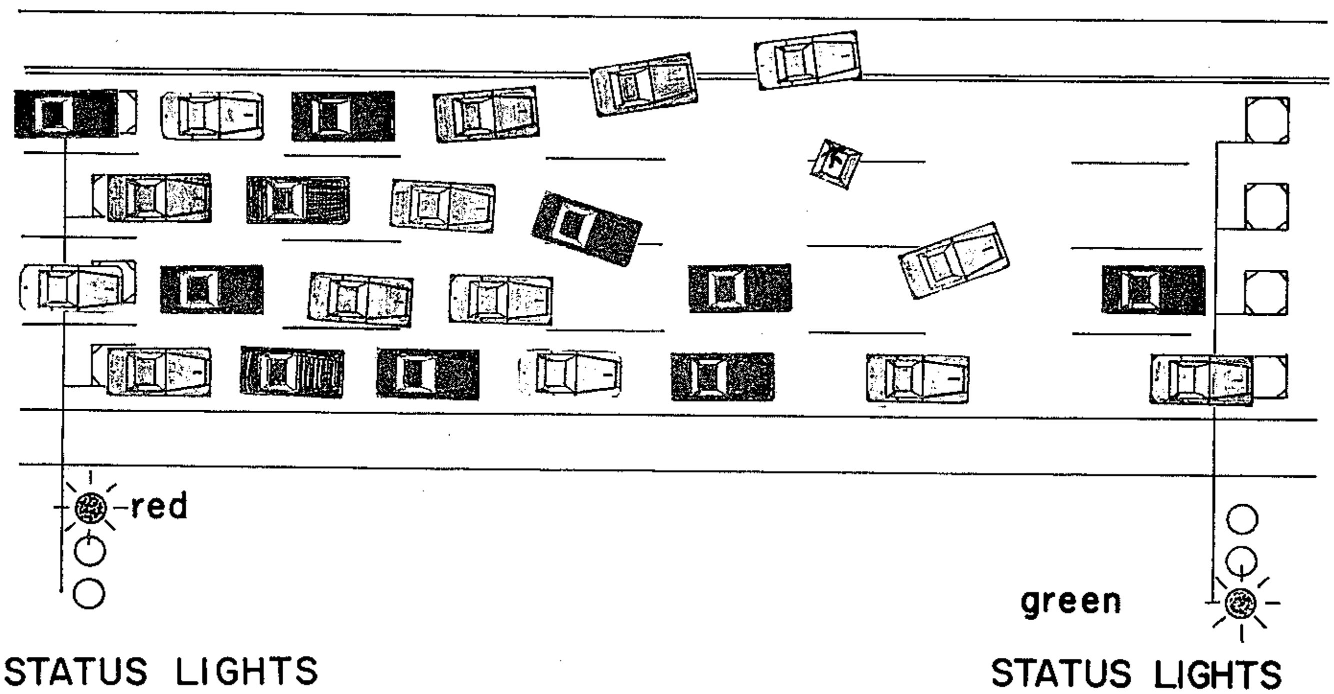


FIGURE 8: INCIDENT DETECTION LOGIC.