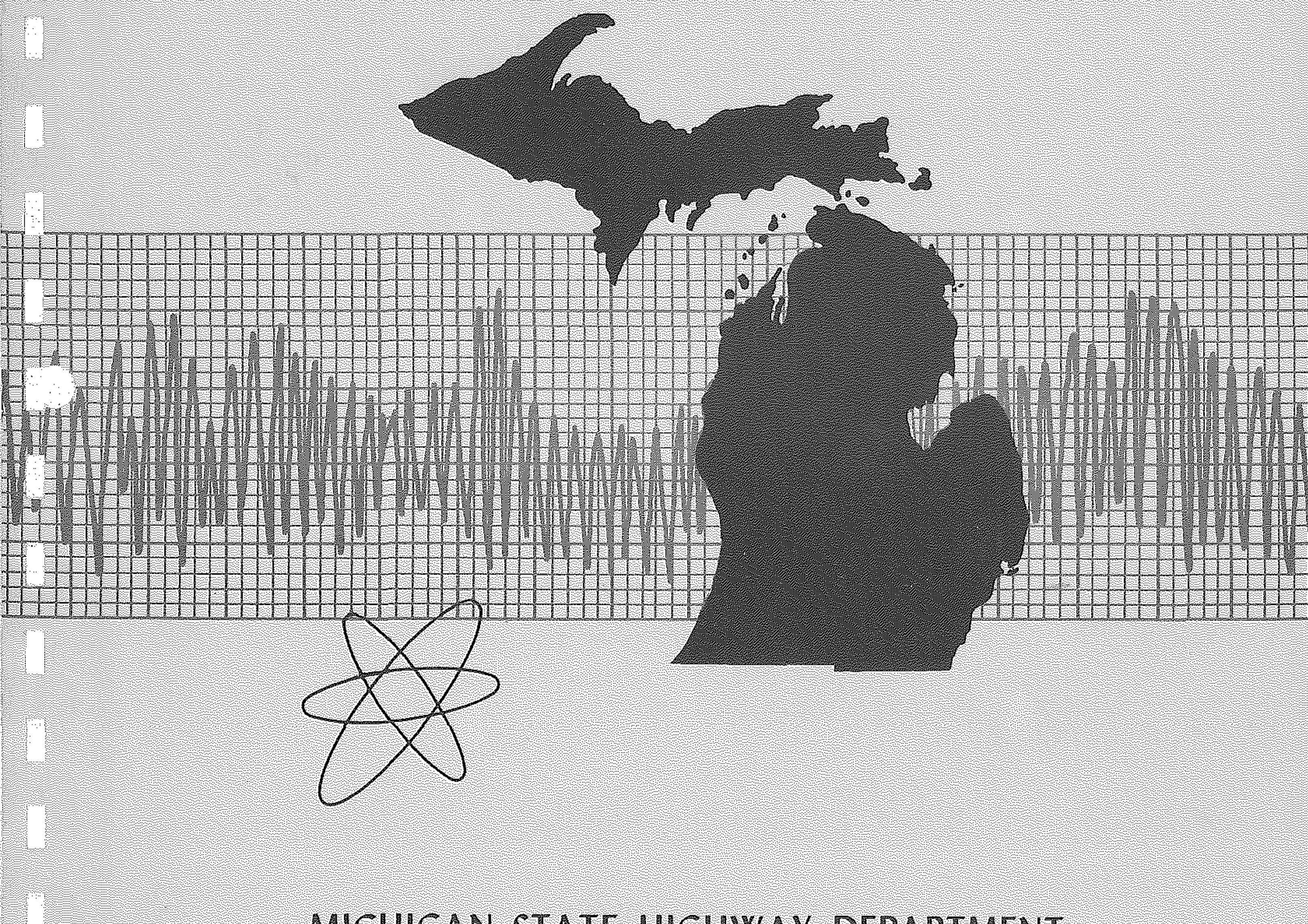
MICHIGAN HIGHWAYS
and
ELECTRONICS



MICHIGAN STATE HIGHWAY DEPARTMENT
LANSING 26, MICHIGAN
John C. Mackie, Commissioner

MICHIGAN HIGHWAYS
AND
ELECTRONICS

MICHIGAN STATE HIGHWAY DEPARTMENT
LANSING 26, MICHIGAN
JOHN C. MACKIE, COMMISSIONER

MICHIGAN HIGHWAYS AND ELECTRONICS

INTRODUCTION

The Michigan State Highway Department has gained a national reputation for being the pioneer in the application of electronic equipment, both in the control of traffic and the building of the highway itself. During the 1930's, when electronic traffic signal controllers were in their infancy, this Department had installed more traffic-actuated signals than any other State. These valuable early lessons gave us the practical experience to determine improvements needed to overcome early deficiencies of this type of equipment. Our testing and research laboratories were responsible for the evolution of many electronic tools needed for the development and improvement of highway techniques and equipment. This background of effort has given us an experienced working force ready to utilize modern electronic equipment and assist in its improvement.

THE FREEWAY TRAFFIC SURVEILLANCE RESEARCH PROJECT

The Michigan State Highway Department is presently conducting a Bureau of Public Roads sponsored research project, which is the largest of its kind ever undertaken, to prove how the latest developments in electronics and other technological advances can be applied to freeway operation. The freeway traffic surveillance research project is being conducted on the John Lodge Freeway in the 3.2 mile long section located between the interchanges of the Edsel Ford Freeway and the Davison Freeway in the City of Detroit. The work of the project is being conducted on a tri-party agreement with the City of Detroit and the Wayne County Road Commission. It is to be programmed over a two-year period and offers an exceptional opportunity to conduct unlimited research into numerous aspects of driver and vehicle behavior on a heavily traveled freeway. The unique nature of this project requires that complete research be performed on all aspects of the project in anticipation that this project will become a permanent installation, be expanded, or that similar projects will be undertaken elsewhere.

The John Lodge Freeway, like others of its type, has proven the extreme popularity of this type of highway to the motorist. Daily traffic volumes far exceed its design capacity, with the result that drivers are travelling the roadway closely spaced at high speed. Under such circumstances, whenever interruptions occur in the traffic stream, there will be vehicle slow-downs and intermittent stoppages, which occur on a daily basis. This phenomenon happens when the traffic stream becomes supersaturated from an increasing number of vehicles. This concentration, or density, of vehicles in an area reaches a point which will recipitate the slow down and eventual stoppages. This usually originates at one location, generates back, and creates an accordian wave action where traffic will proceed in surges rather than smooth continuous flow. When the traffic volume is allowed to approach the critical point, where the freeway area becomes extremely dense with vehicles, this over-load situation will occur regularly. Thus the rate at which vehicles can travel the freeway over the section is greatly reduced.

From previous studies in freeway traffic gap operation and from the Michigan State Highway Department freeway operation investigation, the premise has been raised that it is desirable to obtain freeway traffic operation, which will result in the maximum volume at an optimum speed. The desired result is not merely the maximum number of vehicles that can travel a facility, but is a combination of traffic volume and speed which will provide an optimum traffic flow under the prevailing traffic conditions; therefore, it is desirable that freeway operation be such that a speed is obtained which allows maximum volumes to travel the freeway and result in maximum efficiency. Herein exists the yardstick for measuring the efficiency of operation of the freeway facility. The maximum efficiency of traffic flow is, therefore, defined as the maximum vehicles per unit of time which can travel the freeway and still maintain continuous vehicle flow and will be expressed as vehicles per minute.

This project has as its prime purpose the application of the latest developments of electronic and other related equipment to maximize the freeway operational efficiency. It is possible to visualize an automated highway whereby deficiencies in driver judgment have been removed and substituted for by electronic equipment capable of guiding the vehicle from entrance to exit in complete safety with maximum utilization of the facility. Before this is a reality, there must be much knowledge acquired and transition stages passed before the ultimate is acquired. This is one of the goals of the current research project.

The installation of closed-circuit television in conjunction with a traffic control system are the proposed methods of experimentation to increase operational efficiency of the freeway. An evaluation of the effectiveness of the television surveillance and traffic control system is being made to determine whether the efficiency of freeway operation can be improved. In addition, it is intended that related research will be centered upon the study of freeway traffic flow characteristics directed towards the determination on interrelationships of traffic flow characteristics, new concepts in traffic flow characteristics, as well as driver behavior investigations and studies in geometric design and their effects upon freeway operation efficiency. Sensing equipment, whether it be television or detectors similar to those now being utilized in the project area, will be a very necessary part of an automated highway. We feel that many of the experiences gained from this work will determine the design of sensing devices for any future automated highway.

At the present time it is impossible to place special equipment in each vehicle travelling on the freeway; therefore, we are utilizing the electronic equipment to gather all the information required on traffic patterns and driver behavior, etc. so that by conveying this information to the driver by signal devices, he may drive the freeway in increased numbers with greater safety. This is leaving the "man in the circuit" for the present time. Research will show the human failures which deteriorate the safety and efficiency of travel on freeways, which can be substituted by reliable equipment. Electronic control can substitute for the human control in those areas where the driver's ability is taxed to cope with the situation.

The wide areas of traffic research being undertaken on this project are shown by listing the large number of independent studies which will be conducted. These studies fall into four general groups which are:

I. EVALUATION OF TELEVISION FOR INCREASING FREEWAY OPERATION EFFICIENCY

II. EVALUATION OF TRAFFIC CONTROL SYSTEM

III. EVALUATION OF AUTOMATIC SENSING AND COMPUTER EQUIPMENT

IV. TRAFFIC OPERATIONAL RESEARCH STUDIES

See Appendix 'A' for list of research studies.

This research project, although in its initial stages, has already accomplished several complex objectives. The closed-circuit television system installed on this freeway is one of the most sophisticated systems presently in use for any purpose and is the first large scale application of television for traffic operation and research. Each camera can be controlled remotely for pan, tilt, remote lens change, remote focus, remote iris, remote windshield wipers, and remote shut-down. Special features include transistorized cameras of high resolution pictures in which camera and accessory gear are enclosed in an environmental housing which provides heating in the winter and cooling in the summer.

One problem which had to be solved with the television equipment use on this project was the obtaining of a camera picture, both day and night, under wide ranges of environmental lighting conditions. Equipment now in use on this project permits us to obtain an excellent daylight picture under conditions ranging from bright sunlight to dark cloudy days. A usable night picture is also obtained in the face of headlight glare from oncoming motor vehicles. Many other problems arose which had to be solved. These ranged from protection of equipment from vandalism to long distance transmission of high resolution video pictures free of interference and distortion.

The freeway signal control system being utilized is a pioneer project of the Michigan State Highway Department complete from signal heads to control equipment. The signal head construction along with symbols used on the lane signals, were developed from research performed by the department and is now being accepted and incorporated in national standards. A variable speed sign of matrix design has been developed jointly with General Motors and departmental personnel. The variable speed sign will permit speed messages to be displayed in increments of five miles from 20 to 60 miles per hour. Speeds shown by these signals will be the result of information gathered from sensing equipment on the freeway which is instantly analysed to determine optimum speeds.

There will be a ramp signal at each entrance ramp which will indicate to the motorist whenever it is necessary to close a ramp. Surface traffic signals will be interconnected to the freeway control system so that preferential green time can be established on arterial streets acting periodically as bypass routes for freeway traffic. This makes it possible to handle diverted traffic from the freeway with greater efficiency. The very nature of this integrated signal system requires remote control from a central point. This controller requires that a message be sent from the control center to the various signals. The signals at the remote points respond to these messages and then confirm back that they are in the proper operating position. This system has been designed so that it will automatically tell an operator at a central point whether there are any malfunctions in the system immediately at the time of occurrence. The control system used on this project is an adaptation of control systems used on the automation of railroads. This equipment has already reached advanced stages of design, whereby complex functions can be carried out with complete reliability due to the rugged nature of the equipment and the "fail safe" features of its design.

The need of employing sensing equipment for both signal control and research purposes has required that we evaluate practically all types now on the market suitable for such purposes. The ability of electronic sensing devices to obtain information in copious quantities has required the use of electronic analyzers and computers. We are presently employing equipment which takes the signals received from the sensing devices in the field, analyzes, and performs certain basic computations. A result of one of these computations is the receipt of volume and speed information and the computation of vehicle density and percent of pavement occupancy. We are presently examining and exploring the most direct method of taking this information and preparing it for the initial stage of various type computers now available.

We are already probing the possibility of analyzing the video signal received from a television camera so that a complete pattern of vehicle volumes, speeds, size and placement can be made in a given area. The results of this research should prove the feasibility and provide the building blocks for any future automated highway.

INSTRUMENTATION AND ELECTRONIC RESEARCH

In other activities the Department has been participating in research developments in the field of automatic control of vehicles through representation on the Highway Research Board Special Committee No. 3 on Electronics Research since the beginning of this Committee in 1959. The emphasis on improved methods of obtaining experimental data has resulted in a background of staff experience gained in the last 15 years in electronics and advanced instrumentation methods, and in addition, a full complement of electronic instrumentation equipment. As an illustration of the variety of such instrumentation work the type of measurements which have been made are as follows:
Acceleration, velocity, temperature, strain, deflection, pressure, differential pressure, moisture, density, weight, friction, smoothness, magnetic field strength, frequency, force, color, infra-red absorption, nuclear radiation, time, position, electro-magnetic spectrums, visible light intensity and wave lengths, and others. Most types of measuring transducers and associated electronic equipment both tube and transistor have been designed, constructed, and or, utilized by laboratory personnel.

Research studies illustrating such electronic instrumentation experience are the laboratories experimental studies on pavement design and a series of studies for determining the stresses, the vibrations and deflections of bridges conducted in 1950, 52, 53, 55 and 56. The emphasis on improved methods has also lead to an extensive program of research and development on the Michigan combination neclear gage for measuring soil moisture and density.

The Department's developmental work on earth resistivity measurements resulted in a practical method for making routine soil exploratory work. The "Barnes-Layer" method resulted in a procedure for interpreting field resistivity data in terms of a continuous soil profile rather than individual isolated soundings and advanced the basic method from the experimental stage to a practical and useful method for soil exploration. Measuring equipment developed for this process was modified by the Department and resulted in a device called the "Michimho". As a result of this work, soil resistivity measurements have been used extensively by Highway Departments all over the world.

An additional example of the type of instrumentation developed for research studies in the Michigan State Highway Department Skid Measuring Device which is used to measure the coefficient of friction of the state's trunkline pavements. This device consists of a vehicle-drawn trailer fully automated such that measurement required only the proper vehicle speed and the actuation of one switch to completely perform and record the measurements of the coefficient of friction. The actuation of the switch sets in motion a timed operational sequence of events necessary to the measurement.

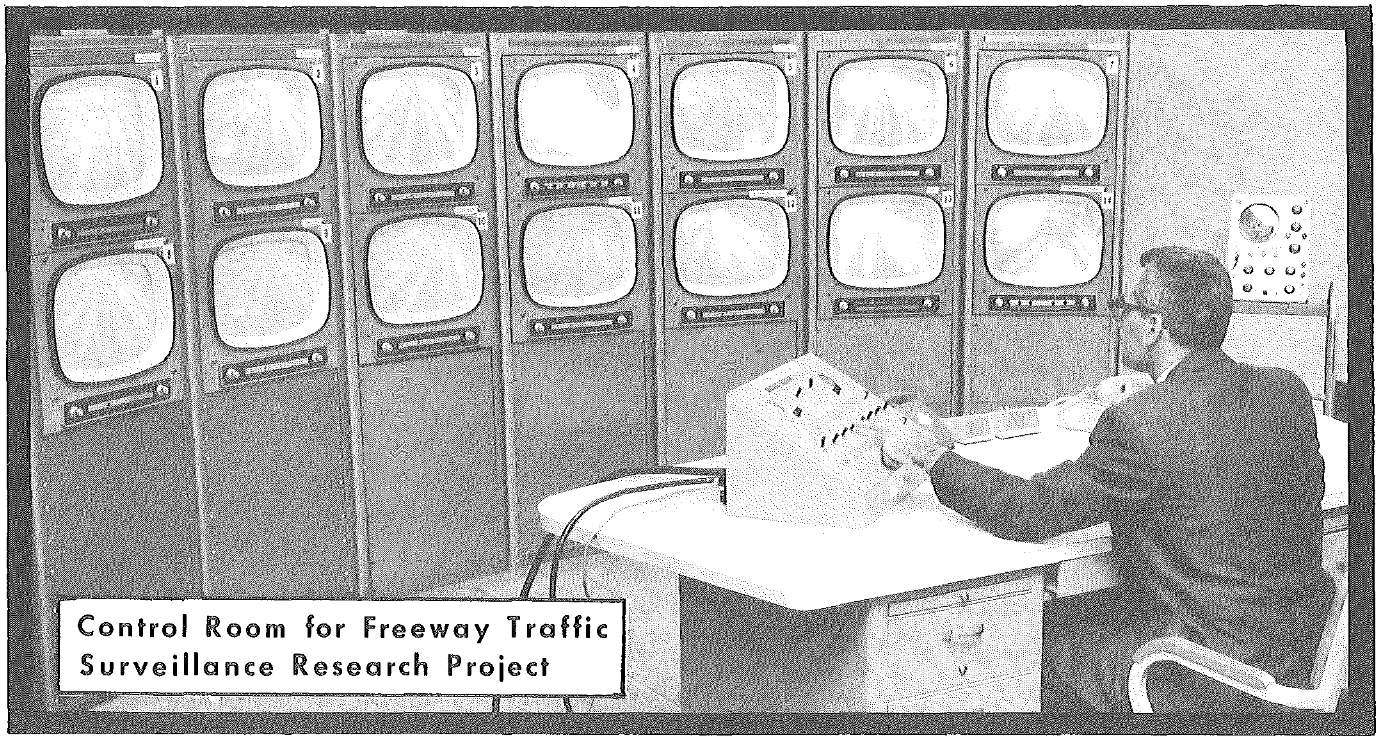
The Department has established technical working arrangements with the Automobile Manufacturers Association and with General Motors, Chrysler and Ford Proving Grounds in connection with research studies of mutual interest. One of these cooperative studies is, "Dynamic Load Aspects of Truck Size-And-Weight". In this study both flexible and rigid pavements were instrumented for measuring warping due to temperature and strain and deflection due to load, and the test vehicles were instrumented to measure dynamic axle load variations by means of axle strain, acceleration and tire pressure change. The Department has also conducted research studies in cooperation with Michigan State, Wayne State, Purdue and the University of Michigan and have working relationships with various technical personnel of these institutions.

Through the development of specifications and the establishing of an acceptance testing program in connection with traffic control devices and associated equipment, the department has the necessary know-how to handle any large scale electronic and instrumentation program and assure that maximum performance is being obtained per dollar expenditure.

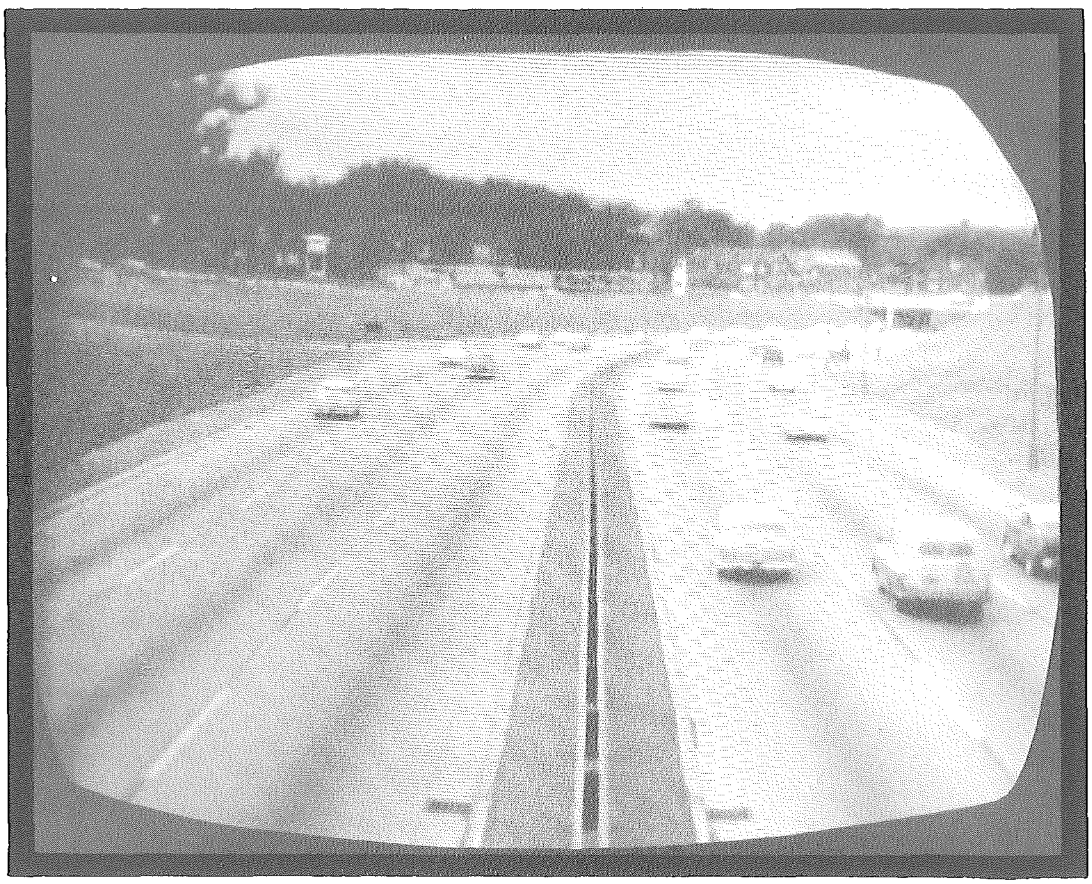
"Automatic Weighing of Vehicles in Motion and Collection of Traffic Data by Electronic Methods", a current research program now being carried on in cooperation with the Bureau of Public Roads, illustrates the Department's interest and capabilities in the area of automation. This program will result in the construction of an experimental dynamic vehicle weighing and measuring system on an Interstate route and the processing of all the resulting traffic data into final tabular form by the use of automatic means and an electronic computer.

In addition to the specifically mentioned application of electronics to the control of traffic and instrumentation used in the construction of highways, the Department has utilized electronics in many of its other functions. Computers have been employed in highway design, programming and various administrative tasks where use of such equipment has resulted in greater accuracy, time savings and efficiency. Photogrammetry work has been considerably augmented by use of electronic devices both in the photographing and analysis of data.

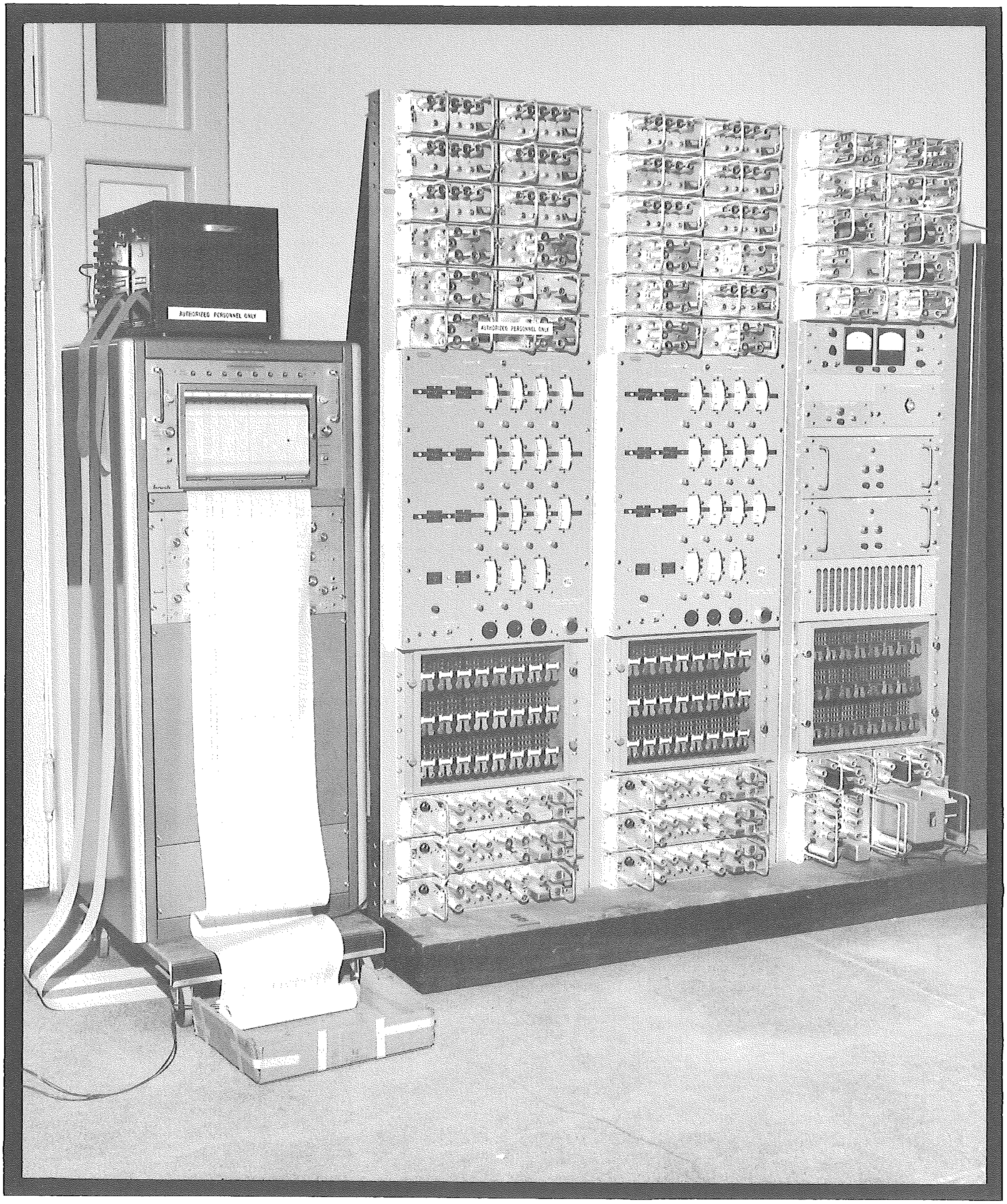
A radio communication system is now being installed which can ultimately be used not only for voice communication but also as a means of telemetering many categories of information gathered in the field. Much of this information can be transmitted in off-peak operation periods so that the maximum use of the facility can be obtained.



Control Room for Freeway Traffic Surveillance Research Project



Freeway Traffic Viewed from Television Monitor Screen



Analyser and Computor for Sensing Equipment Used on Freeway

MICHIGAN IS

READY

WILLING

ABLE

TO UNDERTAKE NEW CHALLENGES

Michigan has the automotive, electronic, and highway building know-how to undertake new projects embodying advanced electronic control concepts. Michigan has the weather and traffic variations required to test new highway concepts under a wide range of actual conditions. Michigan has a record of performance in highway building which justifies confidence that project deadlines will be met. Michigan's road construction costs are lower than the average. Michigan's highway department is an independent branch of State government with its own elected chief executive and its own constitutionally reserved funds. Highway progress in Michigan was overwhelmingly endorsed by a state-wide vote of the people of Michigan this year.

I. AUTOMOTIVE RESEARCH. Michigan is the automobile research center of the world. Here are located the great research complexes of the industry most intimately involved in highway progress.

II. ELECTRONICS RESEARCH. The Institute of Science and Technology at the University of Michigan is carrying on advanced and large-scale projects. Its activities range from basic research to advanced engineering, from conception of an idea to testing of a prototype. It is currently handling $9 million worth of projects, it has a staff of more than 700 persons of whom 284 are professional researchers. Its current projects include work in the fields of computation, analog computers, information processing, sensory subsystems, infrared, and radar. The talent of staff members in this field and related fields from Michigan State University, Wayne State University, and other institutions of higher learning are available to the Michigan State Highway Department.

III. ELECTRONICS IN ACTION. The Michigan State Highway Department has a record of interest and initiative in electronic projects. Its leaders believe in using the tools of science to do a better job. The television surveillance program on one of the nation's busiest freeways; the density control project; the electronic weighing project-- are samples of interest and action in this field.

IV. EXPERIENCED PERSONNEL. The Michigan State Highway Department has a great number of people already experienced in many phases of electronic developments. It is nationally recognized further for its leadership in geometrics and other phases of design work.

V. PERFORMANCE RECORD. In 1957, the Michigan State Highway Department announced its building program for the next five years. That program is on schedule! Last year, Michigan opened the longest non-toll freeway in the nation, and the first border-to-border freeway within a State, Interstate 94 from Detroit to Lake Michigan, 203 miles. Projects once undertaken will be finished on schedule. If a new highway, incorporating advanced electronic features is wanted for operational use by certain deadline, Michigan will meet that deadline.

VI. WEATHER VARIATIONS. A new highway embodying advanced electronic concepts would be tested under a great variety of weather conditions in Michigan. Except for the extremes of deserts and mountains, the Michigan weather pattern reproduces the conditions faced by the vast majority of motorists in the United States. The weather pattern along one possible route for such a new highway would range from days of over 90 degree temperature to days of near zero temperatures or below. The full effects of four distinct seasons are felt in Michigan. A representative test of operational problems in advanced highway concepts can be obtained in Michigan.

VII. TRAFFIC VARIATIONS. Michigan offers the opportunity to test new highway concepts not only under the traffic variations of urban and rural areas, but also under the traffic variations of unique seasonal peaks! In hunting season, traffic volume triples along traffic corridors; the opening of the trout season produces a similar upturn; summer tourists and winter skiers each add a traffic variation beyond the normal variation by hours of the day or by days of the week. This same fact of a greater variety in traffic patterns means an opportunity to test different motoring characteristics--e.g. tent or boat-carrying trailers.

VIII. GREAT LAKES BASIN. Approximately 36% of America's population -- some 65,000,000 people--live within a 500 mile radius of the middle of lower Michigan. And some 2,400,000

Canadians live within this same radius. In this radius lies the agricultural, industrial, and transportation heartland of America. More freight tonnage passes through the locks at Sault Ste. Marie, Michigan, yearly than goes through the Panama and Suez Canals combined! And the opening of the St. Lawrence Seaway brings ocean-going vessels directly to Michigan ports.

IX. INTERNATIONAL TRAFFIC. In Michigan, a highway embodying advanced electronic features can be part of Interstate 75, extending 350 miles overall from Detroit to Sault Ste. Marie, and connecting at either end with bridges to Ontario, Canada, (the Ambassador Bridge in Detroit; the International Bridge at Sault Ste. Marie). This great corridor connects not only with southern States of the United States, but is easily accessible to trans-Canada traffic from the east as well.

X. MORE FOR THE DOLLAR. Michigan can build an advanced design highway at relatively low cost for long mileage. The particular corridor indicated above, for example, would require few interchanges, presents minor grading problems, and is in an area where land cost is low. Yet, it combines both urban and rural characteristics. Michigan's construction costs overall have been consistently below the national average.

XI. DEPARTMENT ORGANIZATION. Michigan's highway department is a distinct and separate branch of government. The highway commissioner--the chief executive--is independently elected on a State-wide ballot. The department operates on constitutionally reserved revenues. It is, therefore, able to make its own administrative decisions and set up its own performance schedules.

XII. PUBLIC SUPPORT. The largest single poll of public opinion on a modern highway building program was taken in Michigan this year! Michigan's program was overwhelmingly endorsed in a State-wide election in which the issue was whether to go forward or retrench in the highway program. Public support for progress in highways--new developments, new ideas--is a matter of incontrovertible public record in Michigan.

APPENDIX A

STUDIES TO BE PERFORMED ON FREEWAY TRAFFIC SURVEILLANCE RESEARCH PROJECT

I. EVALUATION OF TELEVISION FOR INCREASING FREEWAY OPERATION EFFICIENCY

A. Evaluation of Television Equipment for Freeway Traffic Observation

101. Location of Cameras
102. Camera characteristics
103. Camera accessories
104. Transmission facilities and equipment
105. Video recording equipment
106. Simultaneous vs. sequential observation for operation
107. Monitor presentation including orientation map
108. Future development area (camera detector)

B. Evaluation of Monitor Output

109. Scope and limitations of information
110. Accuracy of information
111. Transfer of data from visual to permanent
112. Use for operational purposes
113. Use for research purposes
114. Observer abilities and limitations
115. Grid and markers (distance and speed)

C. Measure of Benefits Derived from Television

116. Time saved in detection, evaluation and dissemination of information on incidents
117. Improvement to traffic operation and safety
118. Effect of notification of public by commercial radio stations
119. Use of other direct notification methods (Hvcom., etc.)

II. EVALUATION OF TRAFFIC CONTROL SYSTEM

A. Operational Features Evaluated by TV

201. Effect of lane closure

202. Effect of speed change

203. Conditions warranting use of control system

204. Effect of ramp closure

205. Obedience study of ramp closure

B. Evaluation of Supervisory Control Equipment

206. Control panel layout

207. Confirmation panel layout

208. Circuitry and method of confirmation

209. Maintenance

210. Operators abilities and limitations in performing control functions

211. Methods of recording control operation

C. Evaluation of Signal Indications

212. Evaluation of lane signals-incandescent, flourescent and neon

213. Development of variable speed sign

214. Development of ramp closing equipment

D. Measure of Benefits Derived from Control System in Addition to Television

215. Reduction in delay and erratic driving by lane closure

216. Reduction in delay and erratic driving by speed signals

217. Reduction in delay and erratic driving by ramp closure

III. EVALUATION OF AUTOMATIC SENSING AND COMPUTER EQUIPMENT

A. Types of Equipment and Capabilities

301. Evaluation of various detectors

302. Evaluation of recording and readout equipment

303. Evaluation of computing equipment for traffic work

304. Evaluation of outputs with present values — 85%, ave., etc.

305. Comparison of density in vehicle/mile with density as percent of time occupancy

B. Equipment as a Supplemental Tool for TV Surveillance Operation

306. Location of detecting equipment

307. Minimum required computer and recording equipment

C. Sensing Equipment to Provide Automatic Control of Signal System

308. Conditions warranting automatic control

309. Equipment necessary to provide desired control

D. Sensing Equipment as a Research Tool

310. Location of detection equipment

311. Minimum requirements for recording and data processing

IV. TRAFFIC OPERATIONAL RESEARCH STUDIES

401. Measurement of travel time by television

402. Travel time related to time of day and day of week and lane of entry

403. Travel time as related to types of vehicles

404. Travel time as related to volumes

405. Travel time as related to speed

406. Travel time as related to density

407. Travel time as related to weather

408. Travel time as related to section

409. Vehicles volume by lane, section, ramp, time of day.

410. Classification of vehicles under various conditions:

Stand	Car & Trailer	Combination
Comp.	Panel & Pickup	Buses
Small	Single On	M. Cycle

411. Lane changing by section, type, volume, density, time of day

412. Lane changes by individual vehicles by condition, section day of week

413. Point speed by lane, vehicle type, time of day, volume, weather

414. Vehicle spacing by type of vehicles under various conditions

415. Spacing as affected by comm. vehicles

416. Characteristics of shock wave—starting from stopped platoon

417. Shoulder usage

418. Effect of slow moving vehicles

419. Improvement of traffic operations at selected locations by closing ramps

420. Improvement of traffic operations at selected locations by signs and markings

421. Improvement of traffic operations at selected locations by reconstruction

422. Effect of length of merging lanes

423. Effect of on-ramp sight distance on merging

424. Effect of incidents on freeway traffic

425. Characteristics of merging traffic

426. Point of maximum effect of incident on following vehicles

427. Effect of radar vehicles on freeway traffic

428. Effect of detector tubes on freeway traffic

429. Effect of parked vehicles on freeway by type and placement

430. Influence of service roads on expressway traffic diversion

431. Lane change in vicinity of ramps

432. Percent of thru vehicles in right lane by section

433. Effect of ramp spacing on freeway traffic.