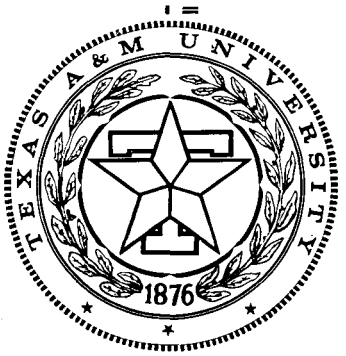

TEXAS TRANSPORTATION INSTITUTE

TEXAS HIGHWAY DEPARTMENT

COOPERATIVE RESEARCH

FREEWAY CONTROL

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

BIBLIOGRAPHY 36-2

SURVEY OF LIBRARY FACILITIES PROJECT

FREEWAY CONTROL

1. Olson, Karl W. A SYSTEM FOR AUTOMATIC VEHICLE LATERAL GUIDANCE. The Ohio State University. Presented at the Highway Research Board meeting, January 1969.

It is clear that substantial savings both in terms of lives and personal property can be achieved through implementation of a fully automatic vehicle control system. This paper presents the results to date of one phase of the overall system study, specifically that of automatic lateral guidance. Preliminary results indicate that the proposed system is feasible on nonreinforced roads. Problems encountered on reinforced highways have been identified and are presented in detail along with a discussion of one possible solution to this problem.

2. Bauer, Herbert J. RESPONSE TO A CB RADIO DRIVER AID NETWORK. GM Research Labgratories. Presented at the Highway Research Board meeting, January 1969.

The need for a method to provide surveillance of roadways has been a source for continuing research for many agencies and activities, including GMR. The Detroit Department of Streets and Traffic is currently operating the GM-sponsored CB Radio Driver Aid Network. This system makes possible the reporting of traffic-related information such as accidents and traffic flow interference. On the basis of earlier demonstration efforts, the system has been expanded to cover the entire Detroit system of surface streets and freeways. The specific functional aspects of the system and a brief description of its major technical equipment are given.

The paper discusses the results of the earlier operations, presents data on current operational activities, the findings of a questionnaire survey conducted by GMR's Transportation Research Department, and the reactions and conclusions resulting from these efforts. The system is viewed as providing a feasible interim solution to the problem of roadway surveillance, incident reporting, and action implementation for the provision of safe and efficient traffic flow.

3. Drew, Donald R. MULTILEVEL APPROACH TO THE DESIGN OF A FREEWAY CONTROL SYSTEM. Texas Transportation Institute. Presented at the Highway Research Board meeting, January 1969.

How does one go about the design of a freeway control system? After more than a decade of experimentation with surveillance and control, progress in the implementation of freeway control systems on existing facilities is still lagging because of the lack of a rational, unified aproach to the design of such systems. This report deals with the definition of the functional and operation requirements for freeway control systems and the actual design and installation of a prototype.

The specification proposed for the design of the prototype control system in this research consists of two objectives: (a) the optimal use of acceptable freeway gaps by merging ramp vehicles, and (b) the prevention of congestion. The underlying philosophy of the first specification is that minimizing intervehicular interference at entrance ramps reduces the probability of rear-end collisions in merging areas due to false starts, reduces the tension on a merging driver, and prevents shock waves from developing on the freeway in the vicinity of entrance ramps. The theory behind this first specification is based on the

utilization of gap availability and gap acceptance models. Behind the second specification is the idea that the prevention of congestion ultimately results in moving more traffic faster. Theoretically, congestion is prevented if demand never exceeds some service volume.

The approach taken in the design of the freeway control system prototype is based on the multilevel concept used so effectively in process control. The freeway is viewed as a single entity with the control law being split into several degrees of sophistication or levels, with the lower levels directed toward recognizing the influence of short-term factors (gap availability for merging ramp vehicles) whereas the higher levels are reserved for factors that influence performance on a long-term basis (freeway capacity reductions due to accidents, incidents or geometric bottlenecks.

4. Haack, Harvey. DESCRIPTION AND EVALUATION OF TRAFFIC CONTROL ON A TWO-LANE HIGH-SPEED, HIGH-VOLUME FREEWAY ENTRANCE. Chicago Area Transportation Study. Presente at the Highway Research Board meeting, January 1969.

This study reports on efforts to solve a serious traffic problem resulting from holiday vacationers returning to the Los Angeles area. Intolerable congestion on Memorial Day 1966 led to emergency measures on July 4th. A form of ramp control provided partial relief. On subsequent holidays, more sophisticated plans were attempted with a variety of results. The data collected and the observations noted provide a wealth of information on a unique application of ramp control and an emerging philosophy in freeway and expressway operation.

5. Brewer, Kenneth A. RAMP CAPACITY AND SERVICE VOLUME AS RELATED TO FREEWAY CONTROL. Texas Transportation Institute. Presented at the Highway Research Board meeting, January 1969.

The problem of establishing a policy for freeway control can be structured into an ordered set of control problems within a hierarchy of levels of control. At each level associated with the hierarchy of the problem structure, an interrelation exists among freeway capacity, freeway demand, ramp capacity, ramp demand, outside freeway lane flow characteristics, ramp merging characteristics, and merging control system operation. The extent to which an optimum control policy can be established at each level of control is directly related to the extent to which the pertinent traffic and control system variables can be interrelated.

6. Buhr, Johann H. TRAFFIC CHARACTERISTICS FOR IMPLEMENTATION AND CALIBRATION OF FREEWAY CONTROL. Texas Transportation Institute. Presented at the Highway Research Board meeting, January 1969.

Using the Gulf Freeway in Houston as the laboratory, a number of traffic characteristics associated with gap acceptance control were studied. Data collection was performed using manual methods, a closed-circuit television system, and an electronic data acquisition system including field sensors and a digital computer.

The ramp traffic characteristics presented include the vehicle performance characteristics of speed, acceleration, and travel time, the relationships among these variables, and the effects of vehicle type and ramp grade on these variables. The behavior of ramp vehicles at the control signal was also studied to determine the starting delay characteristics and stopping position of vehicles at the ramp signal. A frequency distribution of each variable is presented and the applicatior

of the results in the implementation and calibration of merging control systems is discussed.

Several freeway traffic characteristics were also studied. The characteristics were concerned mainly with traffic stability upstream of an entrance ramp and the effect of this stability on the accuracy with which the trajectory of a ramp vehicle can be matched with a freeway gap. Also presented is the relationship between total travel and total travel time, two measures of effectiveness often used in the evaluation of freeway control systems. The possible application of this relationship in the development of warrants for freeway control is indicated.

7. Inose, H. THEORY OF ROAD TRAFFIC CONTROL BASED ON MACROSCOPIC TRAFFIC MODEL. Electronic Letters (Institution of Electrical Engineers, Savoy Place, London WC 2), Vol. 3, No. 8, pp. 385-386, Aug. 1967. HR Abstracts, February 1968.

Centralized and systematic control of traffic signals in urban areas is urgently required for the effective utilization of road networks. Electronics now provides a powerful means for the collection, transmission and processing of information needed for that purpose. A theory of systematic control of traffic signals in urban areas is described. It is shown that for the minimization of delay time of vehicles, preferential offsets should be assigned to the optimum tree in a road network, and the procedure for determining the optimum tree is proposed. For the evaluation of the validity of the theory, computer simulation of traffic has been performed.

8. ASSEMBLY, ANALYSIS, AND APPLICATION OF DATA ON WARRANTS FOR TRAFFIC CONTROL SIGNALS. Paul C. Box and Associates (4050 Dobson St., Skokie, Ill. 60076), March 1967. 74 pp. + 40 pp. appendix. HR Abstracts, February 1968.

The initial work included a review of existing bibliographies, direct contacts with numerous researchers, organizations and individual traffic engineers. The areas of information were divided into six groups as follows: volume, gap availability, gap acceptance characteristics, delay, pedestrians, and vehicular control accidents. A general review covering each of these subject areas is provided. These reviews of existing work have been supplemented by local studies on volume, accidents and delay. The total work performed by all parties has resulted in the development of suggested warrants. The basic variable uses a delay expression. The warrant is sufficiently broad to cover any type of intersection, including those subject to minimum volumes, interruption of continuous traffic concepts, and high-volume driveways. A street systems type warrant is also included. The area of pedestrian signal needs is covered by a third proposed warrant, based on delay due to gap availability vs group size and roadway width. In order to aid future researchers in the area of signal warrants, the bibliography has extensive notations. The single area of greatest significance found for this study is the combined therortical and field validated simulation models. While much remains to be done, this tool offers tremendous potential for multivariant analysis.

9. Federowicz, A. J. A PROPOSAL FOR COMPUTERIZED TRAFFIC CONTROL. Westinghouse Electric Corp. (Research Laboratories, Churchill Borough, Pittsburgh, Pa. 15235), 1967. 18 pp. HR Abstracts, April 1968.

Traffic "rabbits" to pace motorists through tunnels and similar bottlenecks are proposed. The method is based on a computerized traffic control that operates through a scheme of moving illumination, much as a mechanized rabbit leads dogs on race-tracks. A central computer"brain" connected to each light would be aware of all hazards in a tunnel and would know the position, velocity and acceleration of every car at every moment. Although the present scheme is not limited to tunnels, it is presented in terms of tunnels in order to give the reader a specific frame of reference to which to relate the concept. The basic reasons why tunnels present an opportunity for the employment of computerized control systems are set forth, the system is outlined, and the hardware and software necessary to the system are discussed.

10. Wattleworth, Joseph A. EVALUATION OF THE OPERATIONAL EFFECTS OF AN "ON-FREEWAY" CONTROL SYSTEM. Texas Transportation Institute. Presented at the Highway Research Board meeting, January 1968.

This report contains the results of several studies and analyses which have been made for the purpose of evaluating the effectiveness of the "on-freeway" traffic control system on Detroit's John C. Lodge Freeway. This traffic control system consists of a group of overhead lane-use control signals and variable-message speed-control signs on a 3.2-mile section of urban freeway. To achieve this evaluation, an off-peak period set of studies, a peak-period set of studies and a traffic system analysis were made.

Since the studies were made on only one traffic control system on one particular freeway, the results should not be viewed as necessarily applying to the general concept of "on-freeway" controls. It was found that motorists do not decrease their speeds to coincide with the posted speed unless there is an apparent reason to do so. The variable-speed signs were not successful in increasing the flow rate at a critical bottleneck. The effectiveness of the overhead lane-control signals appears to be a function of the freeway demand.

11. Wattleworth, Joseph A. DEVELOPMENT AND EVALUATION OF A FREEWAY RAMP CONTROL SYSTEM ON THE LODGE FREEWAY. Texas Transportation Institute. Presented at the Highway Research Board meeting, January 1968.

An evaluation of the effectiveness of the ramp control system on Detroit's Lodge Freeway traffic operation indicated that traffic operation on the freeway in the peak period was substantially improved when the control system was implemented. Statistics indicate that both total input to the freeway and total travel were not changed by the controls.

Total travel time on the freeway was about 23 percent less during the control period, indicating greater efficiency. This efficiency represents a dollar saving to freeway motorists of about $382,500 per year.

When a freeway ramp control plan is being developed, it is necessary to consider the freeway and the corridor area as an integral system. This same traffic network should also be considered in the evaluation of a control system.

12. Drew, Donald. R. THE DETERMINATION OF MERGING CAPACITY AND ITS APPLICATIONS TO FREEWAY DESIGN AND CONTROL. Texas Transportation Institute. Presented at the Highway Research Board meeting, January 1968.

This paper presents a new approach to the determination of the capacity and service volumes in ramp-freeway merging areas. The capacity of a merging area is based on the critical gap concept and on assumptions regarding the distribution o

gaps in the freeway shoulder lane. The service volumes suggested are developed from considerations of the ramp junction as a queuing system. A level of service can then be provided such that a ramp vehicle has a certain probability of finding the merging area empty. Another measure of level of service is the delay suffered by ramp vehicles. This aspect is treated and charts presented for its determination.

The above merging parameters all involve the critical gap of the junction. This critical gap can be estimated from the geometrics of the ramp-freeway junction by a regression equation, developed through the study of a number of entrance facilities, which relates the critical gap to the length of acceleration lane and the angle of convergence. Relationships are also presented for estimating the entire gap acceptance characteristic from these two goemetric features.

The paper discusses in detail the application of the developed merging parameters in freeway design. A complete design problem is discussed with respresentative design values given as examples. In the section given to design several alternatives are given. The procedure described enables a designer to evaluate these alternatives more rationally and, if compromise is needed, to select the element or location where it will be the least objectionable.

In the section on freeway control the gap acceptance mode of control is discussed in detail. This mode of control materially aids the entering driver to effect a smooth merge with a minimum of disturbance to the freeway flow.

13. Waight, V. H. TRAFFIC CONTROL SYSTEM MAKES REVERSE TUNNEL PRACTICABLE. Public Works (200 S. Broad St., Ridgewood, N.J.), Vol. 97, No. 3, pp. 102-105, Sept. 1966. HR Abstracts, March 1967.

The Caldecott Tunnel connects San Francisco and Contra Costa County. Built in 1937, it consists of two parallel two-lane, one-way bores. As the commuter traffic has increased, it has become a bottleneck. Instead of building a second tunnel the same size, a two-lane, reversible tunnel has been built. A system of movable, flexible barriers and changeable signs has been developed to control the traffic during the rush hours.

Positive barriers are also used to insure that vehicles are prevented access to the lanes of opposing traffic. The traffic is constantly monitored by a closed television circuit. Essential information is broadcast over the normal broadcast bands and can be picked up by the drivers on their car radios. The barriers and the signs are controlled from the surveillance room. The barriers are raised and lowered by electrically operated double-acting air cylinders.

14. Dockerty, A. CLOSED CIRCUIT TELEVISION AS AN AID TO TRAFFIC MANAGEMENT. Journal of the Institution of Highway Engineers (14 Queen Anne's Gate, London SW1, England Vol. 14, No. 2, pp. 15-24, Feb. 1967. HR Abstracts, August 1967.

This paper describes several important aspects related to closed circuit TV in the field of traffic management. An outline of some commercially available equipment is given together with equipment costs. Results of tests designed to answer questions concerned with the choice of fixed or panning cameras for urban intersections are included. The use of closed circuit television equipment for the collection of on-site traffic data is described together with comparisons of traditional and closed circuit television methods. Results of queue length and journey time studies are included.

15. Covault, Donald O. STUDY OF THE FEASIBILITY OF USING ROADSIDE RADIO COMMUNICATIONS FOR TRAFFIC CONTROL AND DRIVER INFORMATION (Progress Report 2). Georgia Institute of Technology. Presented at the Highway Research Board meeting, January 1967.

A new method of driver-roadside communication was tested on the Atlanta Freeway System during daytime and nighttime driving activities in 1964 and 1965. The two related studies attempted to evaluate the effectiveness of roadside radio communication on behavior of the driver as related to his execution of a diverging maneuver from a freeway traffic system. The radio system used, Hy-Com, provides radio communications from the roadside to the driver and consists of a car-mounted receiver and a roadside transmitter.

Volunteer participants were randomly assigned to any one of various test conditions employed in the experiments. Each test condition provided guidance information of varying degrees of advance and exit information by using highway signing, radio communication, or a combination of both. While information was being given to participants, data on traffic characteristics of the driver were collected at various positions along the freeway and the deceleration lane prior to an exit ramp selected for the study. Time-lapse motion photography, the BPR Traffic Analyzer, and manual recording were used.

Analysis of variance and multiple-range test techniques were used to determine differences between driver performances under different levels of information provided during the running of each test condition.

The results indicated that audio messages were as effective as visual messages and when given together the performance of test drivers was generally better than that of test drivers with only visual or audio messages. Indications were that a radio-signing system which will provide the necessary information where needed can be effective and at the same time avoid extensive over-signing- Additional research is required to determine the use of radio as a communication device on a system basis.

16. TRAFFIC CONTROL OF TOMORROW. The Reporter (American Public Works Assoc., 1313 E. 60th Street, Chicago, Ill. 60637), Vol. 32, No. 8, p. 6, Aug 1965.

A glimpse of what may be the electronically controlled traffic of tomorrow was given to more than 700 police chiefs attending their international convention recently. The demonstration featured a 1965 Ford Galaxie convertible, the speed of which was completely controlled by radio signals from roadside transmitters just as it could be on turnpikes and expressways of the near future. In effect, the device electronically notified the driver of the speed limit and adjusted the speed of the car to the signal. A "beep" tone alerted the driver that a speed change signal was being received and, as the car speed changed, a panel on the car's dashboard told the driver what the new speed would be. Officials said that the speed control unit is an adaptation of present automatic speed control optionally available on 1965 Ford Galaxie and Thunderbird passenger cars. With these existing units, the speed is selected by the driver using an indicator dial. The chosen speed is then maintained until the driver wishes to resume manual control, but a memory unit permits him automatically to resume his chosen speed.

17. Wattleworhh, Joseph A. PEAK PERIOD ANALYSIS AND CONTROL OF A FREEWAY SYSTEM. Texas Transportation Institute. Presented at the Highway Research Board meeting, January 1966.

17. Wattleworth, Joseph A. PEAK PERIOD ANALYSIS AND CONTROL OF A FREEWAY SYSTEM. Texas Transportation Institute. Presented at the Highway Research Board meeting, January 1966.

Several methods of operating a system of freeway ramp controls during morning and afternoon rush or peak periods are currently under consideration by traffic engineers. Some ideas on an optimization approach to this control problem are presented here.

The variable to be optimized (in this case maximized) is the total output rate of the critical portion of the freeway system, since this has been shown to be essentially equivalent to minimizing the total travel time occurring to all vehicles using the freeway during the peak period.

In the control system proposed, each freeway entrance ramp (in the direction of the peak flow) is metered at a rate which maintains the total merging flow rate at or below a rate set by a central computer. The central computer determines the optimum merging flow rates by solving an appropriate linear programming problem.

The continuity characteristics of closed traffic systems are used to detect reduced-capacity occurrences (accidents, etc.) and to determine the capacity flow rate at such locations. This information is used as input for a modified L-P model which is solved to determine optimum operation under the existing condition.

18. Fenton, Harry S. LEGAL ASPECTS OF THE UTILIZATION AND DEVELOPMENT OF AIRSPACE OVER AND UNDER FREEWAYS. Highway Research Record No. 78, 1965, pp. 52-64.

The use and development of air rights has turned full circle in the last 50 years. Today we have legal problems concerning the use of airspace above our highways in a new setting. One of the most prominent recent examples of the use of airspace over a highway is the development of four 32-story apartment buildings over the approach to the George Washington Bridge in New York, and in addition a $14 million bus station straddling the same Interstate expressway.

The potential for the use and development of airspace on the Nations highway looms as high as our cities' tallest skyscrapers. The legal problem will undoubtedly equal them in stature.

19. White, Fred S. ANNOTATED BIBLIOGRAPHY ON GAP ACCEPTANCE AND ITS APPLICATIONS. TTI Report 430-7, 1967.

This bibliography annotates articles on gap acceptance, traffic queueing theory, entrance ramp operations, freeway traffic control, traffic surveillance, computer control of traffic, quality of flow-level of service, traffic simulation, methods and instrumentation for measuring traffic characteristics.

20. Burns, D. F. DETAILS AND DESIGN CONTROLS FOR FREEWAY ELEMENTS. ASCE Transportation Eng. Conference - Reprint 193, May 17-21, 1965, 18 pp.

Geometric controls and design features applied to freeways in Minnesota are reviewed; use of design controls as essential elements of initial plan development; also covered are major freeway geometric design features and associated practices such as acceleration and deceleration lanes, ramps and loops, access control in vicinity of interchanges, responsibilities of others for interchange, and costs and safety measures.

21. Drew, Donald R. SOME ASPECTS OF REVERSE-FLOW FREEWAY DESIGN. Presented as a paper at the 46th Annual Meeting of the Highway Research Board, Jan. 16-20, 1967. Highway Research Record No. 172, 1967, pp. 39-53.

This paper is a generalization of the reverse-flow freeway concept in that it suggests some interchange designs which enable ingress and egress directly to and from the at-grade street system rather than the outside freeway roadways. A step-by-step procedure for utilizing this new type of reverse-flow facility is explained. The geometrics of the proposed interchanges are discussed in detail.

22. Gern, R. C. and Joyner, H. R. CROSSROUTE ACCESS DESIGN IN INTERCHANGE AREAS. Highway Research Record No. 59, 1964, pp. 1-8.

This paper describes an analysis of design features which would influence an extension of access control with congestion control in mind. The objective of this research was to develop a design aid which would identify the elements controlling the desirable distance between a ramp terminal and the nearest access route along the cross route. In this research, approximately 60 of the most common and important design situations were studied in detail. For each of the situations the controlling design elements were determined and combined into equations. These equations can be solved to give the proper spacing between ramp terminals and access points along the cross route. In addition a coding or reference system was developed to aid in the definition or description of all possible design situations. Another aspect of the study was the investigation of the use or application of land-use control techniques to reduce conflicts and congestion around interchanges.

23. Pinnell, C. Varnett, J. D., Haynes, J., and Radke, M. GUIDE TO THE SELECTION OF NONDIRECTIONAL INTERCHANGES. TTI Final Report, November 1963, 43 pp.

This research work has included studies of entrance ramp operation, diamond interchange signalization and operation and cloverleaf operation. This report presents data from comparative studies of diamond and cloverleaf interchanges which consider the factors of capacity, efficiency and cost.

24. Satterly, Gilbert T. and Berry, Donald S. SPACING OF INTERCHANGES AND GRADE SEPARATIONS ON URBAN FREEWAYS. Presented as a paper at the 46th Annual Meeting of the Highway Research Board, Jan. 16-20, 1967. Highway Research Board Record 172, 1967, pp. 54-93.

This article considers suitable spacings of interchanges and grade separations as a systems problem. Two objectives were (1) develop and test a model for comparing alternative spacings; and (2) to determine the sensitivity of optimum spacings to changes in values of input parameters. It was found that the proportion of travel via freeway decreased with increases in interchange spacing and that the optimum spacing of interchanges and grade separations is sensitive to changes in time costs and interest rates rather than changes in amortization periods, levels of service, or right-of-way costs.

25. Tipton, William Earl. AN INVESTIGATION OF FACTORS AFFECTING THE DESIGN LOCATION OF FREEWAY RAMPS. A Thesis submitted to Texas A&M University, August 1965.

This thesis investigates the desired movement of entering and exiting traffic at diamond or "X" type interchanges; the effect of freeway ramp configuration on the amount of acceptable gap time; the effect on the amount of acceptable gap time as the distance downstream of an off-ramp increases; and the suitability of various interchange layouts in fulfilling drivers' desires, providing access to the freeway and abutting property, and reducing the interference to arterial street traffic.

26. Betz, Mathew J. and Supersad, Jarnie, N. TRAFFIC AND STAGGERED WORKING HOURS. Traffic Quarterly, Vol. XIX, No. 2, April 1965, pp. 188-203.

This article discusses a plan to test the feasibility of staggering working hours and the effect of such a program on traffic congestion. The method of analysis is applied to a hypothetical city.

27. Drew, Donald R. DETERMINISTIC ASPECTS OF FREEWAY OPERATIONS AND CONTROL. TTI Research Report 24-4, June 1965. 53 pp.

This article is concerned with freeway congestion. Factors to be considered in congestion study include optimum density, optimum speed, and optimum flow. The author comes to three major conclusions:

1. A model of traffic flow analogous to a one-dimensional compressible fluid was found to be statistically significant and conceptually realistic when applied to freeway flow.
2. A generalized microscopic model was formulated based on the car-following theories. Solution of the macroscopic and microscopic equations yields equivalent equations of state.
3. A comparison of the congestion predicting attributes of two control parameters-optimum speed and optimum density-yielded close agreement in defining the time of incipient congestion.

The author also concludes that time lapse photography and contour maps could be helpful in congestion studies. The three principle operational characteristics speed, density, and volume - make it possible to determine three congestion control parameters: optimum speed, optimum density, and optimum flow.

28. Haynes, John J. SOME CONSIDERATIONS OF VEHICULAR DENSITY ON URBAN FREEWAYS. Texas Transportation Institute and Texas Highway Dept., Cooperative Rssearch, Res. Rept. 24-6 (Project 2-8-61-24) April 1965, 61 pp. Highway Research Record 21, 1965, pp. 59-80.

This report includes parts of a general study of the various aspects of vehicular density for use in the control of freeway traffic. Information is provided which may be useful for freeway control methods. The principal features of existing methods used to measure or estimate density are reviewed. Results of aerial photography studies of the Gulf Freeway in Houston are utilized and a field study method is described which yields continuous values of vehicular concentration on certain sections of a freeway.

29. Lynch, Frank L. and Keese, C. J. RESTORING FREEWAY OPERATION AFTER TRAFFIC ACCIDENTS. TTI Bulletin No. 28, pp. 5-18.

This article reports on the effects of traffic accidents on freeway operatio and evaluates methods of reducing delays in restoring normal operation by means of efficient communication and access.

30. Pinnell, C., Drew, D. R., McCasland, W. R. and Wattleworth, J. A. INBOUND GULF FREEWAY RAMP CONTROL STUDY II. TTI Research Report 24-13, July 1965.

The report presents the development, preparation, and results of the Inbound Gulf Freeway Ramp Control Study II in Houston conducted between January 26 and March 12, 1965. Previous studies in 1964 indicated that the control of the Gulf Freeway needed to be expanded and more ramps needed to be metered instead of being closed. The present study was developed to fulfill this need and to allow the evaluation of a trial entrance ramp control signal installation. The results showed sizeable improvements in the overall traffic operation. Study indicated that a better control system would probably be one which was responsive to presen traffic conditions instead of being based on what the freeway traffic conditions were on a typical day several months before.

31. Pinnell, Charles, Drew, Donald R., McCasland, W. R. and Wattleworth, Joseph A. EVALUATION OF ENTRANCE RAMP CONTROL ON A SIX-MILE FREEWAY SECTION. Presented as a paper to the 45th Annual Meeting of the Highway Research Board, January 17-21 1966. Highway Research Record 157, 1967, pp. 22-76.

This article reports on the development of an automatic surveillance and control system for the Gulf Freeway in Houston, Texas. The report furnishes the results of studies conducted before, while, and after the control plan was in effect. The development of control procedure and the effect of controls on freeway and surface street operation is presented and discussed. A discussion of the results of a study of public opinion regarding the control plan is also presented an an evaluation of the control action and probable future research in this area is summarized.

32. Santerre, Gary Lee. AN INVESTIGATION OF THE FEASIBILITY OF IMPROVING FREEWAY OPERATION BY STAGGERING WORKING HOURS. TTI Research Report 24-16, Januayy 1967, 52 pp.

This research investigates the feasibility of staggering working hours in Houston, Texas and evaluates the impact that staggered working hours of selected traffic generators would have on spreading the demand over a longer period of tim and thereby reducing the congestion on the morning peak period operation of the Gulf Freeway. The author views the concept favorably.

33. Wattleworth, Joseph A. and Berry, Donald S. PEAK PERIOD CONTROL OF A FREEWAY SYSTEM: SOME THEORETICAL CONSIDERATIONS. Presented as a paper at the 43rd Annual Meeting of the Highway Research Board, January 13-17, 1964. Highway Research Record 89 1965, pp. 1-25.

This paper contains a series of considerations pertaining to the control of a freeway system during peak traffic periods. An arbitrary street and/or freeway system is analyzed to determine the objective function or goal of operation for the system. An input-output analysis is used. A theory of flow at bottlenecks is developed to explain the reduction of flow rate and the increase of flow rates. Several criteria for control techniques are examined. Finally, a linear programming model of the operation of a freeway system is presented.

34. Wattleworth, J. A., Drew, D. R., McCasland, W. R., and Pinnell C. THE DEVELOPMENT OF AN AUTOMATIC FREEWAY MERGING CONTROL SYSTEM. TTI Research Report 24-19, 1966.

This paper presents the operational aspects of the merging control equipment in use at the Telephone Road interchange on the inbound Gulf Freeway. The equipment is being used to evaluate several control theories but at the time this paper was written had not been installed for a period of time sufficient to allow a report on the comparison of theories. This paper presents only a discussion of the equipment operation and some general observations regarding the traffic operation under the different modes.

35. Athol, Patrick. HEADWAY GROUPINGS. Presented at the 44th Annual Meeting of the Highway Research Board, January 11-15, 1965. Highway Research Record 72, 1965, pp. 137-155.

This article discusses the behavior of traffic studied in terms of headway groupings. The need for these data arose from studies in control techniques for merging traffic and ramp metering. A single detector, located over one lane of the expressway, records the arrival of a vehicle and either the occupancy or speed of that individual vehicle. Data are recorded on punched paper type with headways recorded to 0.01 sec. The analysis is conducted on a digital computer.

36. Buhr, Johann Hermann. THE FREEWAY ENTRANCE RAMP MERGING CONTROL SYSTEMS. A Dissertation submitted to the Graduate College of the Texas A&M University, Jan. 1967, 101 pp.

It was the purpose of this research to formulate a merging control system designed to both relieve freeway congestion and materially aid ramp drivers in the merging maneuver, to evaluate the control function through an investigation of its parent relationships, and to discusss the application of the control function in the merging control of freeway on-ramps.

37. Buhr, Johann H. TRAFFIC INTERACTION IN THE FREEWAY MERGING PROCESS. TTI Report 430-5, 93 pp.

This paper deals primarily with the behavior of time headways between vehicle as they traverse a section of highway immediately upstream of an entrance ramp. The importance of this information in the control of the merging process is discussed and a relationship, developed from the interaction of gap stability and gap acceptance characteristics, is suggested as a rational control function for merging control. The lane changing behavior of drivers in the vicinity of an entrance ramp was also studied.

38. CALIFORNIA TRIES TO STOP WRONG-WAY ENTRIES. Western Construction News, Vol. 40, No. 7, July 1965, p. 92. Highway Research Abstracts Vol. 36, No. 3, Mar. 1966, p.

This explains the reason for new signs being installed on freeways to prevent accidents from wrong-way entires in California.

39. Carvell, James Demus Jr. A STUDY OF FREEWAY OFF-RAMP DESIGN AND OPERATION. A Thesis submitted to the Graduate College of the Texas A&M University, January 1966 54 pp.

The objectives of this research are to evaluate the effect of off-ramps on freeway operation as related to deceleration distance and to study the capacity of off-ramps as related to their ability to move traffic from the freeway to the service road or arterial street system.

40. Drew, D. R., Lamotte, L. R., Wattleworth, J. A. and Buhr, J. H. GAP ACCEPTANCE IN THE FREEWAY MERGING PROCESS. Presented as a paper to the 46th Annual Meeting of the Highway Research Board, Jan. 16-20, 1967. Highway Reserrch Record 208, 1967, pp. 1-36.

This study is the first phase of a 4-year program on freeway merging undertaken by the Bureau of Public Roads to (a) furnish more detailed information on the effect that geometric variables have on the merging or ramp traffic, (b) develop usable distributions of traffic variables for simulation programs, and (c) develop an optimum ramp metering and merging control system. Emphasis is on collection and collation of gap acceptance characteristics. The theoretical development of models and useful parameters for describing the merging process include the derivation of the forms of the mean and variance of the delay to a ramp vehicle in position to merge and the treatment of the variability of critical gaps and gap acceptance among drivers through the identification of the representative forms for both critical gap distribution and gap acceptance functions. Thro the application of "individual record probit analyses" simple, statistically significant relationships between the percent gap acceptance and gap size are established.

41. Gazis, Denos C. SPILL-BACK FROM AN EXIT RAMP. Presented at the 44th Annual Meeting of the Highway Research Board, Jan. 11-15, 1965. Highway Research Record 89, 1965, pp. 39-46.

The problem of control of an oversaturated system comprising an expressway, a highway, and an exit ramp leading from the expressway to the highway is discussed. A traffic light is assumed to control the intersection of the exit ramp and the exit highway. The operation of this traffic light is determined which minimizes the delay of vehicles served by the entire system.

42. Hess, Joseph W. RAMP-FREEWAY TERMINAL OPERATION AS RELATED TO FREEWAY LANE VOLUME DISTRIBUTION AND ADJACENT RAMP INFLUENCE. Highway Research Record 99, pp. 81-116, 1965.

This report is a continuation of the report "Capacities and Characteristics of Ramp-Freeway Connections". It terminates the analysis of the data collected during the nationwide freeway ramp capacity study. It also contains an analysis of considerable data collected in a 1963 nationwide study of weaving areas by a crew of Bureau of Public Roads - junior engineers.

The emphasis in this report is on equations for determining traffic volumes in lane 1, the right-hand freeway lane, at merging and diverging sections along the freeway. It tells how to forecast when overloading will occur on a section immediately up-stream from an exit ramp, given certain freeway and ramp volumes. Seventeen nomographs, derived from the equations are introduced to provide a fast graphical solution to design and operational volumes.

Auxiliary lane usage between on- and off-ramps is discussed and a method of capacity analysis is illustrated with a sample problem. Curves are used to give

the cumulative percentage of ramp vehicles on and off the auxiliary lane, related to the distance traversed.

Two-lane on-ramp operation is analyzed from the standpoint of the multiple merges taking place. Two-lane off-ramps are analyzed to show the ramp lane volume distribution and the diverging volume movement which takes place as off-ramp vehicles leave the main traffic stream at the ramp nose. The contribution of the deceleration lane to capacity and smooth operation is stressed.

43. Hulbert, Slade, and Beers, J. WRONG WAY DRIVING: OFF-RAMP STUDIES, PHASE I. Presented at the 44th Annual Meeting of the Highway Research Board, Jan. 11-15 1965. Highway Research Record 105, 1966, pp. 1-7.

This study discusses the use of roadway signs (Do Not Enter) which are painted red and white rather than the conventional black and white. Red and white signs elicited earlier and more correct response than did the black and white signs.

44. May. Adolf D. Jr. GAP AVAILABILITY STUDIES. Presented at the 44th Annual Meeting of the Highway Research Board, January 11-15, 1965. Highway Research Record 72, 1965, pp. 101-136.

This paper describes one approach being undertaken for improving ramp metering operations, and includes a description of previous studies pertaining to gap availability, fitting mathematical distributions, and gap acceptance. Reference is made to some 45 articles. The expressway surveillance projects pilot detection system was employed to record on punched paper tape the arrival time of each vehicle, and the running average occupancy level in the expressway lane adjacent to, and just upstream of three of the four ramps to be metered in the near future.

45. McDermott, J. M. OPERATIONAL EFFECTS OF AUTOMATIC RAMP CONTROL ON NETWORK TRAFFIC Presented as a paper to the 46th Annual Meeting of the Highway Research Board, Jan. 16-20, 1967. Highway Research Record 202, 1967, pp. 1-31.

This paper reports on an experiment in ramp metering on Chicago's outbound Eisenhower Expressway. Entrance ramp traffic was automatically metered each peak period by modified traffic signals which permitted only one vehicle at a time to enter the expressway-ramp merging area. Metering rates were determined through computer analysis of existing expressway traffic conditions as measured by surveillance detection system. It was concluded that this method is a possible solution to ramp congestion.

46. Reddy, M. Skiramulu. QUANTITATIVE EVALUATION OF THE EFFECTS OF MERGING VEHICLES ON FREEWAY OPERATION. A Dissertation submitted to the Graduate College of the Texas A&M University, January 196[illegible], 137 pp.

The objective of this research includes four specific studies: (1) to develop a model to study the effect of merging on freeway operation quantitatively in terms of "easiness to flow," (2) to evaluate the model and to determine the reasonableness of the parameters developed, (3) to study the effects of ramp geometrics on freeway operations, and (4) to suggest a method for improving the design of entrance ramps.

47. Wattleworth, Joseph A., Buhr, Johann H., Drew, D. R., and Gerig F. OPERATIONAL EFFECTS OF SOME ENTRANCE RAMP GEOMETRICS ON FREEWAY MERGING. Presented as a paper at the 46th Annual Meeting of the Highway Research Board, Jan. 16-20, 1967. Highway Research Record 208, 1967, pp. 79-122.

This article reports on a study made of entrance ramps having a side range of geometrics. The geometric elements for which the operational effects were most carefully evaluated are acceleration lane, length, angle of convergence,and ramp grade. Operational characteristics examined were speed of ramp vehicles at the ramp nose and at the merge point, change of speed of ramp vehicles between the ramp nose and the merge points, the accepted gap number, and the distribution of points of entry onto the freeway. General conclusions regarding entrance ramp design are presented.

48. Worral, R. D., Coutts, D. W., Echterhoff-Hammerschmid, H. and Berry, D. S. MERGING BEHAVIOR AT FREEWAY ENTRANCE RAMPS: SOME ELEMENTARY EMPIRICAL CONSIDERATIONS. Presented as a paper to the 45th Annual Meeting of the Highway Research Board, Jan. 17-21, 1966. Highway Research Record 157, 1967, pp. 77-107.

A report is given of a study of gap acceptance and merging behavior at freeway entrance ramps conducted by the Civil Engineering Department of Northwestern University. The phenomenon of merging behavior is discussed in general terms, and a conceptual framework for the analysis of gap acceptance and rejection at a freeway entrance ramp is presented. A brief critical review of various previous empirical and theoretical research work in the field is also made.

A series of empirical studies was conducted during the summer of 1965 at one left-hand and one right-hand entrance ramp in the Chicago area. The ramps were similar. Included are empirical comparisons of alternative analytical techniques a consideration of gap acceptance and merging behavior as both dynamic and static phenomenon, an evaluation of critical gap size and gap structure, an analysis of the effect of relative merging speed on gap acceptance criteria, and a study of multiple vehicle merges.

A selected bibliography of reference materials on entrance ramp design and merging behavior, and a computerized analysis technique developed at Northwestern University for handling large quantities of empirical data are presented.

49. Dawson, Robert F., and Michael, Harold L. ANALYSIS OF ON-RAMP CAPACITIES BY MONT CARLO SIMULATION. Highway Research Record 118, 1966, pp. 1-20.

In recent years thousands of miles of freeway-type highways have been constructed to provide for the safe, convenient and efficient transportation of persons and goods. Access to these facilities is provided by on-ramps designed to merge ramp traffic into the highspeed, highvolume traffic stream. The efficiency of traffic movement on freeways, and the extent to which the potential capacity of freeways can be realized, depends in part on the adequacy of the access facilities. Improperly designed entrances limit the volume of traffic that can use an expressway and generate congestion that often extends back onto the local system.

50. Duckstein, Lucien. CONTROL OF TRAFFIC IN TUNNELS TO MAXIMIZE FLOW. Presented to the 45 th Annual Meeting of the Highway Research Board, Jan. 17-21, 1966. Highway Research Record 154, 1967, pp. 1-23.

This paper reports on an experimental automatic traffic flow control system based on speed and flow measurements implemented in the Holland Tunnel South Tube.

51. Radke, Milton L., EVALUATION OF THE TELEVISION SURVEILLANCE SYSTEM FOR THE BAYTOWN-LAPORTE TUNNEL. TTI Research Report 47-1, February 1966, 40 pp.

This paper refers to the proposal that a closed circuit television surveillance be installed that would cover the entire length of the Baytown Tunnel and the approaches to the tunnel. Five objectives were planned in connection with this installation. They included such generalities as investigation, evaluation, developments, analyzation, and the set-up of operational studies. Six conclusions were drawn from the results of this research.

52. Drew, D. R. GAP ACCEPTANCE CHARACTERISTICS FOR RAMP-FREEWAY SURVEILLANCE AND CONTROL. TTI Research Report 24-12, July 1965, 43 pp.

This investigation was concerned with gap acceptance characteristics and merging delay characteristics for six inbound entrance ramps on the Gulf Freeway surveillance and control project. The interaction of the two traffic streams is described in terms of a "critical gap", a time gap that the merging vehicle is just as likely to accept as reject.

Merging vehicles were divided into two groups - those in which the driver rejected gaps before finally accepting a gap and those in which the driver of a ramp vehicle accepted the first gap. The former was referred to as "stopped" vehicles and the latter as "moving" vehicles was found to be about 20 percent higher than for moving vehicles. In addition, it was concluded that the critical gap for the merging maneuver from an entrance ramp is independent of freeway volume but is apparently affected by ramp geometrics and ramp control.

53. Drew, D. R. and Keese, C. J. FREEWAY LEVEL OF SERVICE AS INFLUENCED BY VOLUME AND CAPACITY CHARACTERISTICS. TTI Research Project 24-3, January 1965, 75 pp.

This report deals with urban freeway volume (demand) and capacity characteristics, and their application to freeway design and operation. Vital volume characteristics include the distribution of demand during the peak hour, the lane use distribution of vehicles on freeways. A theoretical approach to providing a rational relationship between capacity and level of service is formulated utilizing a hydrodynamic model and based on an energy-momentum analogy. This theory is applied in the preparation of a table of Freeway Design Service Volumes to be used in determining freeway main lane requirements. Applications are made of these demand and capacity characteristics to freeway operations and design.

54. Keese, C. J., Pinnell, C., and Drew, D. R. HIGHWAY CAPACITY: THE LEVEL OF SERVICE CONCEPT. TTI Bulletin No. 34, presented at the 35th Annual Meeting of the Institute of Traffic Engineers, Boston, Mass. October 21, 1965, pp. 1-48.

Analyzes the practicality of utilizing the "level of service" for determining capacity, rather than "possible" of "practical" capacities.

55. McCasland, William R., and Wattleworth, Joseph A., STUDY TECHNIQUES FOR PLANNING FREEWAY SURVEILLANCE AND CONTROL. Texas Transportation Institute. Presented at the 44th Annual Meeting of the Highway Research Board, Jan. 11-15, 1965. Highway Research Record, 99, 1965, pp. 200-223.

In this study, four study techniques, found to be quite useful in planning the peak period freeway surveillance and control activities on the Gulf Freeway in Houston, are presented. Data from these studies can be used to plan peak period ramp controls because the demand and capacity can be estimated at each bottleneck and to plan arterial street controls to provide for diverted traffic. The data are also useful in before and after comparisons.

56. Pinnell, Charles. GULF FREEWAY SURVEILLANCE AND CONTROL PROJECT. Reprint from Traffic Quarterly, January, 1966, pp. 31-46.

This paper presents a brief resume of studies on freeway surveillance and control during the first part of a five year research project on the Gulf Freeway in Houston, Texas.

Basic objectives such as development of criteria for design and operation of automatic surveillance and control systems are described and some early findings are outlined.

It was evident early in the project that considerable benefits could be realized through surveillance and control.

57. Stern, Stan. TRAFFIC FLOW DATA ACQUISITION USING MAGNETIC-LOOP VEHICLE DETECTORS. Presented as a paper before the 45th Annual Meeting of the Highway Research Board, January 17-21, 1966. Highway Research Record 154, 1967, pp. 38-52.

Magnetic-loop vehicle detectors will be used to acquire validation data for System Development Corporation's digital computer simulation of traffic flow in a freeway diamond interchange. Actual interchange performance will be monitored by direct measurement of vehicle parameters (count, size, and velocity) leading eventually through the validation process to a realistic simulation model. Techniques were developed to extend existing loop detector capabilities, permitting direct measurement of vehicle parameters for the first time. Experiments were conducted to determine detector sensor loop response characteristics. The techniques described in this paper can be used to determine vehicle velocity and/or size directly, in addition to vehicle counting.

58. Keller, Oliver. CENTRALIZED TRAFFIC CONTROL BY SIGNALS & TELEVISION. Traffic Engineering, Vol. 36, No. 11, August, 1966, pp. 21-25.

This report deals with the merits of a centralized traffic control through television and signals, thus permitting observance of most traffic performances by way of television.

59. Cosgriff, R. L., English, J. J., and Roeca, W. B. AN AUTOMATIC SYSTEM FOR LONGITUDINAL CONTROL OF INDIVIDUAL VEHICLES. Highway Research Record No. 122, 1966, pp. 7-18.

This paper includes a short description of the traffic situation variables, the requirements on the system, a description of the system itself, and a discussion of the performance of the system. Theccontrol problem is not treated in great detail.

60. Drew, D. R. STOCHASTIC CONSIDERATIONS IN FREEWAY OPERATIONS AND CONTROL. TTI Research Report 24-5, June 1965, 54 pp.

The stochastic considerations in freeway operation were based on describing the longitudinal distribution of traffic mathematically. The Erland frequency distribution was utilized to describe the distribution of individual vehicles, and a "moving queues" model is formulated to explain the tendency of vehicles to platoon. Applications of the stochastic approach to traffic operations, freeway surveillance, and geometric evaluation and design are suggested. A comparison of the congestion predicting attributes of critical queue length with other control parameters yielded close agreement in defining the time of incipient congestion. The moving queue parameter developed is capable of automatic detection, measurement, and control.

61. Wheeler, Robert J., and Tory, Elmer M. THE USE OF THE FLUX PLOT IN TRAFFIC CONTROL. Traffic Quarterly, Vol. XIX, No. 3, July 1965, pp. 369-383.

This paper deals with the use of experimental volume-concentration relationships in the study and prevention or limitation of kinematic waves in a number of common traffic situations.

62. Drew, D. R. and Dudek, C. L. INVESTIGATION OF AN INTERNAL ENERGY MODEL FOR EVALUATING FREEWAY LEVEL OF SERVICE. TTI Research Report 24-11, June 1965, p. 1-8

This article deals with theory formulation, measurement of appropriate traffic characteristics, for theory verification and recommendations for applications. Included are measurement of acceleration noise on the Gulf Freeway to test the hypothesis that acceleration noise represents the "internal energy" of a traffic stream, determination of the effects of such geometrics as grades of the facility on acceleration noise and of the effects of operational control procedure such as ramp metering on acceleration noise. Recommendations are discussed for the application of energy parameters in freeway design and operation and the application of the energy concept to the quantitative description of freeway level of service. It is shown how this is a simple means for describing the level of operation on a facility - free flow, stable flow, unstable flow, and forced flow.

63. May, A. D. and Keller, Harmut E. M. NON-INTEGER CAR-FOLLOWING MODELS. Highway Research Record No. 199, 1967, pp. 19-32.

This paper deals with the investigation of a continuum of one-integer car following models for the development of deterministic flow models, which describe interrelationship between flow characteristics.

64. Gafarian, A. V., Hayes, E., and Mosher, W. W., Jr. THE DEVELOPMENT AND VALIDATION OF A DIGITAL SIMULATION MODEL FOR DESIGN OF FREEWAY DIAMOND INTERCHANGES. Highway Research Record No. 208, 1967, pp. 37-78.

The paper contains a brief description of the total project plans leading to a valid simulation model for design of diamond interchanges. The major portion of the paper describes work completed through February of 1966.

65. Howie, George W. UNIFORM TRAFFIC CONTROL DEVICES FOR CITIES AND COUNTIES. Presented to the 51st Annual Purdue Road School, March 29-April 1, 1965. Printed in the Engineering Extension Series, No. 119, pp. 56-60.

This paper presents a general, theoretical discussion of ideal traffic control devices.

66. Michael, Harold L. THE NEED FOR UNIFORMITY. Presented to the 52nd Annual Road School, Purdue University, Lafayette, Indiana, March 28-31, 1966. Printed in the Engineering Extension Series, No. 123, pp. 91-96.

This article discusses the need for uniform signs and signals, and requirements of traffic control devices, and uniformity of control at intersections.

67. Miller, Alan J. COMPUTERS IN THE ANALYSIS AND CONTROL OF TRAFFIC. Traffic Quarterly, Vol. XIX, No. 4, October 1965, pp. 556-572.

This paper discusses computer control of traffic. Computer control is suggested in timing, speed funnels, quantity control, route control, and vehicle control. Control of isolated junctions and networks is considered.

68. Petersen, S. G. and Schoppert, D. W. MOTORISTS' REACTIONS TO SIGNING ON A BELTWAY. Highway Research Record No. 170, 1967, pp. 1-34.

This paper reports on a study made to obtain and evaluate information from motorists on the kinds of sign messages they need and desire to drive a beltway. Three signing concepts resulted from this study:

1. Provide orientation through the consistent application of a series of sign elements which will provide sequential and confirmatory information for the motorist.
2. Establish route numbers and route names as the primary elements of interchange guide signs and reserve the use of place names for selected locations where they give the motorist directional orientation which could but not otherwise be provided.
3. At the interchange of a radial route with a beltway, limit signing destinations to route intersections, regional areas, and identifiable physical features on the beltway route, and exclude destination names except as a supplemental guide not normally repeated in the interchange signing sequence.

69. Robinson, Carlton C. COLOR IN TRAFFIC CONTROL. Traffic Engineering, Vol. 37, No. 8, May 1967, pp. 25-29.

This article discusses the use of color in traffic control to convey meanings to drivers.

70. Roth, Walter J., and De Rose, Frank, Jr., INTERCHANGE RAMP COLOR DELINEATION AND MARKING STUDY. Highway Research Record No. 105, 1966, pp. 113-125.

This paper applies to two study locations where color coding was applied to edgemarking, delineation, and signing; blue was used for advance exit signing. Evaluation was made only on the blue coding for the exit ramps, although white coding was applied to the through roadway and yellow to the entrance ramps. Evaluation was based on observations made prior and subsequent to color installation. Analysis of the results revealed that the channeling of traffic into existing lanes occurred farther in advance of the exit ramp with a reduction of 20 to 32 percent in erratic driving maneuvers. Ninety percent of the motorists interviewed stated they received definite benefit from the color scheme.

71. Box, Paul C. ACCESS CONTROL AND ACCIDENT REDUCTION. Municipal Signal Engineer, Vol. 30, No. 3, pp. 27-30, May-June 1965. Highway Research Abstract, Vol. 35, No. 11, Nov. 1965, pp. 8-9.

This paper discusses the application of access controls, intersection controls, and reconstruction to prevent an increase in traffic accidents. The discussion illustrates the development, negotiations and agreement, design, and before and after effects of such an improvement in Skokie, Illinois. One of the major problems produced by development of access control is the difficulty of obtaining the agreement of abutting property owners.

72. Gwynn, David W. ACCIDENT RATES AND CONTROLS OF ACCESS. Traffic Engineering, Vol. 37, No. 2, Nov. 1966, pp. 18-21.

It is a study comparing accidents, injuries, accident rates, etc. on highways with controlled access to those without access control.

73. Lundy, Richard A. THE EFFECT OF RAMP TYPE AND GEOMETRY ON ACCIDENTS. Highway Research Record No. 163, 1966, pp. 80-119.

This paper reports on a study made to learn more about freeway ramps, to determine which geometric features play important roles in ramp safety, and to classify these features according to ramp type and relative safety merits. Results are presented indicating that some factors (ramp type, relation of freeway to ramp grades, fixed objects, speed change, lane lengths, speed at on-ramp noses, and off-ramp radius) affect the accident rate while other factors (on-ramp curvature, ramp lighting, ramp traffic volumes, and the magnitude of the ramp central angel) do not seem to affect the accident rate.

74. Radke, M. L. FREEWAY RAMP CONTROL REDUCES FREQUENCY OF REAR-END ACCIDENTS. TTI Project Report No. 24-21, Nov. 1966, 24pp.

The principal objective of this study was to determine the effectiveness of ramp controls in reducing the rate of accidents on or adjacent to a freeway. The study area included the inbound lanes of the Gulf Freeway in Houston. The accident rate for the 12 month period following installation of ramp controls was compared with the rate for the preceding 12 month period.

The type of accident most prevalent was the rear-end collision. Some of the factors contributing to the high accident rate on this facility were ramp locatic geometric design, "roller coaster" effect of freeway grades, and illegal entrance to the freeway.

Results indicated that the ramp control system reduced both the frequency o accidents and number of high accident locations. The total number of accidents during the morning peak period was reduced by approximately 50 percent after installation of the ramp controls.

75. Smith, Richard N. SURVEILLANCE OF ACCIDENT LOCATIONS BY ELECTRONIC PROCESSING METHODS. Highway Research Record No. 188, 1967, pp. 90-126.

This paper reports on a study concerned with the development of computer tabulations which would aid in the identification, priority rating, and detailed analysis of accident problem locations. The report contains systems diagrams fo

the system as a whole and for the accident concentration selection routine. The "traffic log," which is a complete geometric and traffic record of the highway system, is also described.

76. Carrothers, J. A. COMPUTER CONTROL SYSTEMS. Traffic Engineering, Vol. No. 6, No. 12, Sept., 1966, pp. 49-50.

This report deals with the use of computers in traffic control systems, making the point of lower cost and greater flexibility in design.

77. Mulinazzi, T. E. CORRELATION OF DESIGN CHARACTERISTICS AND OPERATIONAL CONTROLS WITH ACCIDENT RATES ON URBAN ARTERIALS. Joint Highway Research Project Report No. 14, Purdue University, Lafayette, Ind., September, 1966, 127 pp.

This paper reports on a study made to evaluate the design characteristics and operational controls which affect traffic accident rates on an urban arterial street where full control of access is not practical. Data taken from test streets were analyzed by a simple correlation coefficient analysis, a multiple linear regression technique, and a case study approach. The study found that traffic accidents on an urban arterial decreased as the volume on the arterial decreased, the number of signals per mile decreased, the amount of parking decreased, and the number of heavily used driveways per mile decreased.

78. Marks, Harold, and Spitz, Salem. A REVIEW OF TRANSPORTATION ASPECTS OF LAND-USE CONTROL. NCHRP Report, 1966, 41 pp.

The purpose of this paper is basically to provide a better understanding of the effectiveness of existing land-use controls on the continuing utility of transportation systems and to establish principles or guidelines for developing land-use controls that will be stable and effective in preserving the investment in transportation systems. The study was to consist of a literature search and canvass of selected highway departments and other agencies concerned with transportation planning. Administration of land-use controls, access controls, and design controls which will effectively preserve the utility of the highway is ultimately involved with implementation techniques. Because many non-transportation factors have a substantial influence on decision making, it is essential that over-all community objectives be adequately evaluated in the development of principles and guidelines or their ultimate value will be limited.

79. Theissen, George J., SURVEY OF THE TRAFFIC-NOISE PROBLEM. Journal of the Acoustical Society of America, Vol. 37, No. 6, p. 1179, June 1965, Highway Research Abstract, Vol. 35, No. 10, Oct., 1965, p. 15.

This paper discusses the reduction of traffic noise. Distance is an intimate part of this approach and involves the control of substantial land areas. An effective solution can be found in an integrated legislative approach involving land development, zoning, road planning and layout, and noise bylaws. In the latter field, a great deal of experience in many states and countries, covering several years, is now available.

80. Tipton, William E., Drew, Donald R., and Spencer, Roger Q., STUDY OF FREEWAY ACCESS VIOLATIONS. Similar report in TTI Research Report 65-1, Highway Research Record No. 152, 1966, pp. 66-102.

This article reports on a study whose purpose was to: (a) catalog types of access violations on controlled-access facilities, (b) to determine the extent and causes of access violations, and (c) to determine the effectiveness of various designs and control features to prevent access violations. Five types of access violations accounted for 63.2% of the total reported: (a) separation strip crossing, exit where no exit ramp exists; (b) median crossing; (c) separation strip crossing, entrance where no entrance ramps exist; (d) unattended vehicle on shoulder; and (e) crossing entire freeway system. The primary cause of access violations was found to be the convenience of the violation route, generally because there was no ramp available or there was no grade separation available. The study of effectiveness of corrective measures indicated that signs were rated as only 22% effective. Curbs, chain link fences, and posts with barrier cable had high effectivensss ratios.

81. Covault, D. O., Dervish, T., and Kanen, A. A STUDY OF THE FEASIBILITY OF USING ROADSIDE RADIO COMMUNICATIONS FOR TRAFFIC CONTROL AND DRIVER INFORMATION. Highway Research Record No. 202, 1968, pp. 32-66.

This paper reports on a test conducted on the Atlanta Freeway System to determine the effectiveness of roadside radio communication in providing information to the drivers. Time-lapse motion photography, the BPR Traffic Analyzer, and manual recording were used. Analysis of variance and multiple-range test techniques were used to determine differences between driver performance under different levels of information provided during the running of each test condition. The results indicated that audio messages were as effective as visual messages and when given together the performance of test drivers was generally better than that of test drivers with only visual or audio messages.