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Freeway Operations Bibliography 1964-1968

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FOREWORD

This annotated bibliography is concerned with references on freeway operations subsequent to 1964.

The Freeway Operations Committee was organized in 1960, and one of its first tasks was the preparation of a Freeway Operations Bibliography which was published in 1961 as HRB Bibliography 28. It included some 165 references and contained an author and publisher index. The Committee during the past four years has spent considerable effort in preparing this annotated bibliography because of interest and usage of the earlier bibliography, because of the rapid growth in publications in this area of research, and due to the recognized need for references which are annotated. Special recognition is given to Alger F. Malo who served as Chairman of the Freeway Operations Committee during the first six years of its existence, and who provided the leadership for the various committee activities including the preparation of these bibliographies.

The primary emphasis of this bibliography is directed toward the influence of traffic stream characteristics and design on freeway operations. Other subjects such as study techniques, theoretical studies, control devices, safety, and motorist services when related to freeway operations are also included.

This volume has been divided into sections and subsections as shown in the Table of Contents. In each subsection the references are listed in alphabetical order by authors. To facilitate the locating of desired references, an author and publisher index is provided.

Donald Drew, a member of the Freeway Operations Committee and, during the time of preparation of this bibliography, Associate Professor of Civil Engineering, at Texas A & M University's Texas Transportation Institute, was Chairman of the task group responsible for the preparation of this annotated bibliography. Members of the task group were Donald Covault of the Georgia Institute of Technology and Joseph Treiterer of Ohio State University. Recognition is also given to the Texas Transportation Institute and the Texas A & M Libraries for their assistance and support of this endeavor.

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SECTION 1

GENERAL REFERENCES

- 1.01 "Canadian Officials Strive to Improve Roads," Traffic Engineering, Vol. 35, No. 12, September, 1965, pp. 11-12 and 37-40.
- Descriptor: inadequate facilities for transportation.
- The cause of today's traffic jams is not the automobile but our failure over centuries to provide adequate street and highway facilities to keep up with the developing means of transportation.
- 1.02 FENTON, Harry S. "Legal Aspects of the Utilization and Development of Airspace Over and Under Freeways." Highway Research Record 78, 1965, pp. 52-64.
- Descriptor: air rights.
- 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.
- 1.03 HAIGHT, FRANK A., "Annotated Bibliography of Scientific Research in Road Traffic and Safety." Operations Research, Special Transportation Science Issue, Vol. 12, No. 4, Nov.-Dec. 1964, pp. 976-1039. Highway Research Abstract, Vol. 35, No. 4, April, 1965 p. 9.
- Descriptors: traffic; simulation; safety; engineering; transportation.
- The subject matter of this bibliography overlaps several fields that are specifically excluded. The bibliography purports to be complete in the category of traffic. Selection of publications has been more difficult in the other four areas: traffic engineering, transportation, simulation and safety.
- 1.04 "Highway Capacity Manual, 1965." Highway Research Board Special Report 87, 1965. 397 pp.
- Descriptor: highway capacity.
- This book is concerned with highway capacity and considers traffic characteristics, capacity and level of service and the factors affecting them, intersections, weaving, ramps, expressways, bus transit, and streets and highways without access control.
- 1.05 LODER, JOHN L. "Freeway Environment and Aesthetics," Traffic Engineering, Vol. 36, No. 5, Feb. 1966, pp. 25-28.
- Descriptor: beautification.
- This report deals with the methods of making freeways more attractive to the eye, such as making the freeway seem to be part of the nature, other than a cement monster evading to beauties of the country side.
- 1.06 LOW, DANA E. "Air Rights and Urban Expressways." Traffic Quarterly, Vol. XX, No. 4, October 1966, pp. 467-482.
- Descriptor: air rights.
- This article considers the right to use the space above freeways. Use of railroad and highway air rights are reviewed. Legislation concerning freeway air rights is mentioned and possible uses for such space are discussed.
- 1.07 MICKLE, D. GRANT. "The National Cooperative Highway Research Program." Traffic Quarterly, Vol. XX, No. 4, October 1966, pp. 483-501.
- Descriptor: research.
- This article discusses the creation and organization of the National Cooperative Highway Research Program and reviews briefly its research projects.
- 1.08 "The Milwaukee County Expressway System," Traffic Engineering, Vol. 34, No. 5, February 1964, pp. 40-41.
- Descriptors: organization, interchanges.
- This report deals with the overall development of the Milwaukee County Expressway. It will include 22 miles of Interstate highway in its total of 54 miles of approved freeways. By 1969 it is expected to be fully operational making Milwaukee the hub of a roadway system that will provide non-stop travel to all of Wisconsin's neighbors.
- All major interchanges are fully directional in design; i.e. left turns leave the thru-roadway from the left and enter from the left.
- 1.09 NUSSBAUM, ERNEST. "Computers and the Traffic Engineer." Traffic Quarterly, Vol. XVIII, No. 1, 1964, pp. 49-62.
- Descriptor: computers.
- This article reviews the history of computers in traffic engineering and considers its future role in traffic planning.
- 1.10 "Research on Road Traffic." Gt. Britain Road Research Laboratory, Dept. of Sci. and Indust. Res. 1965, 505 pp. Highway Research Abstract, Vol. 35, No. 11, Nov. 1965, p. 8
- Descriptor: traffic flow.
- This book is the companion volume to "Research on Road Safety," published in 1963. It covers the work which the laboratory has carried out to discover methods and principles which practicing engineers, planners and administrators can use to facilitate traffic flow. The subjects covered include prediction of the amount of traffic on a new road, traffic theory,

the capacity of road systems including intersections, traffic control, etc.

- 1.11 "What Freeways Mean to Your City." Automotive Safety Foundation, Jan. 1964, Highway Research Abstracts, Vol. 34, No. 8, Aug. 1964, pp. 3-4.

Descriptors: impact; design; location; traffic safety.

This article discusses freeway development, location, and design; freeway impact on land value and business; the relation of freeways to industrial development, community recreation, and urban renewal; and the effect of freeways on traffic safety.

- 1.12 WHITE, FRED S. "Annotated Bibliography on Gap Acceptance and Its Applications." TTI Report 430-7, 1967.

Descriptor: gap acceptance.

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.

- 1.13 YASEEN, DAVID W. "The British Motorway." Traffic Quarterly, Vol. XIX, No. 3, July 1965, pp. 413-427.

Descriptor: freeway systems in Great Britain.

The purpose of this article is to describe the state of inter- and intraurban freeways in Great Britain. It covers policies and expenditures, control, a freeway system presently being constructed, and the prospects of an intraurban freeway.

SECTION 2

PLANNING

- 2.01 AUTOMATIVE SAFETY FOUNDATION, "Freeway-Parking Developments." Automative Safety Foundation, 1964, 77 pp. Highway Research Abstract, Vol. 35, No. 7, July 1965, pp. 1-2.

Descriptor: freeway parking facilities.

The purpose of this study was to investigate the possibilities for developing integrated and coordinated freeway parking facilities in urban areas. The study was limited to existing freeways and programmed projects on the federal-aid primary and interstate systems where the design was completed for alignment.

- 2.02 CHACY, KENNETH D. "Ground Transportation in the Years Ahead." Traffic Quarterly, Vol. XVIII, No. 2, 1964, pp. 188-201.

Descriptor: mass transportation.

This article reviews mass public transportation of the past and discusses the need for and requirements of a future mass transit system.

- 2.03 GILBERT, KEITH. "Economic Balance of Transportation Modes," Traffic Engineering, Vol. 34, No. 1, Oct. 1963, pp. 17-25. Highway Research Abstracts, Vol. 34, No. 2, Feb. 1964, p. 14.

Descriptor: economics of transportation modes.

This report is an analysis of economic balance of transportation modes undertaken with the objective of narrowing the range within which the choice of a "best" transportation system may be.

- 2.04 HACE, LESTER A. "Considerations Affecting the Choice of Urban Transportation Systems." Traffic Engineering, Vol. 37, No. 8, May 1967, pp. 36-40.

Descriptor: transportation systems.

This deals with the importance of continuous, comprehensive transportation planning as an essential criterion for support of transportation facilities in urban areas.

- 2.05 HEITEL, JOSEPH J. "A Method of Estimating Design Hourly Traffic Volumes." Highway Research Record 72, 1965, pp. 88-100.

Descriptor: traffic study.

This paper reports on a study made to develop a method for estimating traffic volumes in the 30th highest hour at any location on the rural State trunk highway system, where the 30th highest hour traffic volumes are not directly available, by utilizing the existing relationship between the 30th highest hour and average annual daily traffic at the permanent traffic recorders.

- 2.06 "Highway System Classification: A Legal Analysis: Part II." Highway Research Board Special Report 85, 1965, 134 pp.

Descriptor: highway classification.

This report considers statutory provisions concerning three highway system categories, i.e., the secondary State highway systems, under the control of the State highway departments; the systems of highways under the control of such political subdivisions of the State as counties, towns, and townships; and the municipal systems. The appendices present a summary of statutes pertaining to classification of highways below the primary state level, statutes and cases cited, and a drafting guide for highway system classification legislation.

- 2.07 HUTCHINSON, B.G. "A Planning Morphology for Transportation Systems." Traffic Quarterly, Vol. XX, No. 3, July 1966, pp. 347-360.

Descriptor: systems planning-methodology.

This paper discusses the current understanding of the concept of a system and available knowledge on general problem-solving and planning processes appropriate to the solution of systems problems.

- 2.08 JOHNSON, PYKE. "The Human Side of Urban Transportation." Traffic Quarterly, Vol. XVIII, No. 3, 1964, pp. 321-334.

Descriptor: highway planning.

This article discusses the roles of the Highway Research Board and its Department for Urban Transportation Planning in the development of urban transportation plans. The department's organization is presented in detail.

- 2.09 LASH, MICHAEL, U.S. Bureau of Public Roads, "Highway Planning and Community Conflict," Presented as a paper at the 43rd Annual Meeting of the Highway Research Board, January 13-17, 1964. Similar report in Highway Research Record No. 69, 1965, pp. 1-17.

Descriptor: location.

This paper discusses the types of community conflicts that develop when a new freeway is proposed through an urban area. The analysis is made chiefly through a case study where the events are based on facts and describe accurately the chief events and conflicts that developed over a span of twelve years between a state highway department and a local community and its officials over the choice of a freeway location through a city. The case study stresses the need for better procedures that involve the public in the decision in a more constructive way in harmony with the democratic philosophy of government.

- 2.10 LEIPER, JOSEPH MC C. "Queens - Long Island Corridor: Urban Transportation Laboratory." Traffic Quarterly, Vol. XVIII, No. 3, 1964, pp. 335-348.

Descriptor: urban transportation.

This article discusses in detail the development of an urban transportation system to accommodate a 60% growth in a New York area in the last decade. A great deal of attention is paid to the organi-

- zations entering into the program. The Long Island Railroad and East River Tunnel are discussed. A possible demonstration program is considered.
- 2.11 LEVINSON, HERBERT S., AND RON, ARTHUR T. "Observations on Urban Change and Planning." *Traffic Quarterly*, Vol. XVIII, No. 1, 1964, pp. 15-16.
- Descriptor: planning.
- The purpose of this essay is to suggest relevance to transportation planning as a specialized element in the broad array of urban development planning.
- 2.12 "A Manual for Interchange Area Planning," Penn. State Planning Board, June 1963, *Highway Research Abstracts*, Vol. 34, No. 4, April 1964, p. 4.
- Descriptor: interchange-planning and development.
- This report deals chiefly with the interchange and its planning and developing.
- 2.13 MATTSON, J.O. "Urban Transportation: Problems Still Before Us." *Traffic Engineering*, Vol. 35, No. 6, March 1965, pp. 14-16.
- Descriptor: urban problems.
- The problem of urban transportation is discussed in this article. The article considers transportation planning, limits on authority, freeways, freeway air space and automated highways.
- 2.14 MICKLE, D. GRANT, "The Role of the Highway in Urban Development." *Traffic Engineering*, Vol. 36, No. 7, April 1966, pp. 32-35.
- Descriptor: urban highways.
- In this study a series of propositions that should be adopted with regard to highways and their role in such development programs is discussed.
- 2.15 MORLOK, EDWARD K., HAY, GEORGE A., AND CHARNES, ABRAHAM. "Toward Optimal Planning of a Two-Mode Urban Transportation System: A Linear Programming Formula." Presented as a paper before the 45th Annual Meeting of the Highway Research Board, Jan. 17-21, 1966. *Highway Research Record* 151, 1966, pp. 41-98.
- Descriptor: urban transportation system - mathematical model.
- This paper reports on a study to develop an analytical methodology or model for finding the optimal combination of two modes in providing transportation service. The specific case treated was that of providing automobile transport facilities and possibly some rapid transit facilities in a radial, downtown oriented corridor. The objective was to find that combination of facilities which minimized transport costs including both capital and operating costs of transit and auto transport during the design or horizon year. The nature of the cost functions for the two modes and the constraints related to capacity, travel times, and model choice was such that the problem could be characterized within the framework of linear programming.
- 2.16 OSBORNE, HENRY W., "Design Considerations for Large Urban Transportation Networks." *Traffic Engineering*, Vol. 35, No. 6, March 1965, pp. 25-27.
- Descriptor: urban transportation networks - design.
- Metropolitan transportation networks are discussed in the article. It points out eight features that must apply to future public transit systems for larger cities. Close studies show the rapid transit is the only sensible road ahead and the cheapest.
- 2.17 OSTROWER, DONALD A. "Highway Location -- The Computer Vs the Brain." *Highway Research Record* 53, 1964, pp. 2-3.
- Descriptor: highway location - computers.
- This paper attempts to take some of the mystery out of the computer and to outline ways in which it is being used and misused in highway location and also to demonstrate the absurdity of using certain dollar value or ration approaches to the location of highways. This paper discusses a computer's use and misuse and its strong and weak points.
- 2.18 PERAZICH, GEORGE, AND FISCHMAN, LEONARD L. "Methodology for Evaluating Costs and Benefits of Alternative Urban Transportation Systems." *Highway Research Record* 148, 1966, pp. 59-71.
- Descriptors: traffic congestion; parking space.
- This paper discusses how increasing traffic congestion, growing inadequacy of parking space, and problems of urban blight which can be solved only through wholesale rebuilding are combining in cities all over the world today to focus attention, among other aspects of urban planning, on the role of transportation systems. The physical means of getting people to and from work, school, stores, health, recreation facilities etc., as well as the means of delivering goods to and from factories, warehouses, etc. . . , both individual and commercial is increasingly coming to be recognized as an organic factor in determining the design, character, and rate of a city's growth. There is a natural demand on engineers, economists, and city planners to give systematic consideration to the question of how new transportation systems may be designed and old ones revamped to provide the maximum in benefit at the minimum in cost. The basic alternatives in most cities are the private automobile, bus and truck service.
- 2.19 PIKARSKY, MILTON, "Comprehensive Planning for the Chicago Crosstown Expressway." Presented as a paper to the 46th Annual Meeting of the Highway Research Board, Jan. 16-20, 1967. *Highway Research Record* 180, 1967, pp. 35-51.
- Descriptor: planning.

This article reports on a study method developed in planning the Chicago Cross-town Expressway. Basic structure of the method was built on independent study groups which developed their own criteria and methods of analysis to arrive at comparative evaluation of proposed alternative alignments. The three basic areas of study were: Traffic and Engineering Aspects, Impact on Existing Communities, and Potential Land Use Improvements.

- 2.20 QUINBY, HENRY D. "Coordinated Highway-Transit Interchange Stations." Paper presented at the 44th Annual Meeting of the Highway Research Board, Jan. 11-15, 1965. Highway Research Record 114, 1966, pp. 99-121.

Descriptors: operations; interchanges.

This study discusses the extensive planning and research which has been conducted in the past twelve years on method attracting and accommodating the various access modes of travel to and from the stations. The objective of these studies was to provide coordinated and integrated highway-transit interchange facilities necessary to the success of the system and to the alleviation of major corridor congestion. Station planning criteria and observations are presented in their several aspects. Access mode distributions, parking stall capacities, loading roadways, and facilities for walkers, feeder transit, taxis, etc. . . . are described and discussed. It is emphasized that system and station planning is a continuing process.

- 2.21 REED, MARSHALL F. AND FUTRELL, R.E. "Multiple Project Scheduling of Preconstruction Engineering Activities." Highway Research Record 87, 1965, pp. 29-56.

Descriptor: resource planning and scheduling.

Systematic methods for scheduling the preconstruction engineering and right-of-way activities of the various state highway programs are revealed in several approaches. In each approach the schedules are arrived at by allocating the assumed fixed pool of classified manpower resources to a priority array of programmed objects. The "balance-period" approach in particular is discussed. Computer programs discussed include: multishop, workload-smoothing, (MS)²; resource allocation and multiproject scheduling (RAMPS); man-scheduling program; resource planning and scheduling methods (RPSM).

- 2.22 ROBERTS, PAUL O. AND SOBERMAN, RICHARD M. "A Vehicle Performance Model for Highways in Developing Countries." Traffic Quarterly, Vol. XXI, No. 3, July 1967, pp. 443-462.

Descriptor: planning model.

This article describes a model developed to provide planners with vehicle performance information needed to make rational planning decisions at both project and systems levels. This model may be used either to evaluate a single road-link or as a sub-component of a larger study.

- 2.23 ROBERTS JR., PAUL O. AND SUHRBIER, JOHN H. "Link Analysis for Route Location." Highway Research Record 77, 1965, pp. 19-47.

Descriptor: highway location - computer methods.

This paper illustrates the use of some of the new techniques and analysis methods in the location of a short segment of new interstate highway in eastern Massachusetts. The project was undertaken primarily to aid in the further development and testing of recent developments, and in every phase of the project an attempt was made to use the most modern techniques and methods of analysis available. The purpose of this paper is to present the most significant findings of this study. This paper has described the application of several computer-based methods to highway location and design problems.

- 2.24 ROBINSON, CARLTON. "Automobile Will Play Role in Future Urban Transportation." Traffic Engineering, Vol. 35, No. 9, June 1965, pp. 10-12, 32-33.

Descriptor: transportation - future of the automobile.

This article discusses the importance of the automobile in designing freeways, roadways, etc. One of the most serious aspects of the greater reliance on private automobiles has been the decline of public transit. And, yet, a public transport system is needed in any large metropolitan area. This article tries to determine the future of the automobile as being the greatest asset to urban transportation.

- 2.25 STOVER, VERGIL G. AND BLUMENTRITT, CHARLES W. "User's Manual for the Texas Large Systems Traffic Assignment Programs." T.T.I. Research Report 60-6, November 1966, pp. 161.

Descriptor: assignment - computer programming.

This report presents a detailed discussion of systems programs. It covers machine requirements, control programs, the preparation of node map and network data cards, program descriptions, network-link data card formats and deck configurations, examples of computer printout, spider network programs, and network plot programs.

- 2.26 STUART, DARWIN G. "Coordinated Freeway -- Park Developments." Traffic Quarterly, Vol. XXI, No. 3, July 1967, pp. 355-378.

Descriptor: roadside developments.

This article deals with the development and distribution of parks in urban areas. The uses of such parks, land acquisition, and week-end travel patterns are discussed.

- 2.27 SUHRBIER, JOHN H. AND ROBERTS, PAUL O. "Engineering of Location: The Selection and Evaluation of Trial Grade Lines by an Electronic Digital Computer." Highway Research Record 83, 1965, pp. 88-113.

Descriptor: route location - computer application.

One aspect of highway route location problem, vertical profile selection and evaluation, has been chosen to show how digital computer hardware and software advances now under development can be used to improve the decision-making capabilities of the engineer.

- 2.28 TURPIN, ROBERT D. "Evaluation of Photogrammetry and Photographic Interpretation for Use in Transportation Planning." *Photogrammetric Engineering*, Vol. 30, No. 1, Jan. 1964, pp. 124-130. *Highway Research Abstracts*, Vol. 34, No. 5, May 1964, pp. 15-16.

Descriptor: photography in planning.

This report discusses the use of photography in coping with complex problems of data collection for the projection of future transportation networks.

- 2.29 "Urban Freeway Development in Twenty Major Cities." *System Planning; Design Concepts; Progress*. Automotive Safety Foundation, Aug. 1964, 64 pp. *Highway Research Abstracts*, Vol. 35, April 1965, p. 1-2.

Descriptor: freeway systems.

The Automotive Safety Foundation, in planning this study, examined the current status of urban interstate progress in the larger urban areas from U.S. Bureau of Public Roads records to determine those which would produce the maximum amount of data concerning freeways and freeway systems. Twenty cities were selected containing the various types of systems and current developments in freeway planning and design, and providing good geographic coverage of the country. Indications are that the Interstate System is being developed at a rapid pace in urban areas, but there still is a considerable portion of the planned non-interstate urban system yet to be built.

- 2.30 WICKSTROM, GEORGE Y. "Daily Work Travel and Peak Hour Traffic." *Traffic Engineering*, Vol. 34, No. 5, February 1964, pp. 14-18.

Descriptor: traffic volumes.

A method is presented for deriving peak hour travel volumes from a relationship between daily work and total travel. This paper explains the derivation of the relationships, compares the results of their application with known data, and indicates how this method can be used to obtain estimates of future peak travel volumes on highway facilities.

SECTION 3

DESIGN

A. FREEWAY DESIGN

- 3.01 BURNS, D.F. "Details and Design Controls for Freeway Elements." ASCE Transportation Eng. Conference - Reprint 193, May 17-21, 1965, 18 pp.
- Descriptors: geometric controls; design features.
- 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.
- 3.02 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 172, 1967, pp. 39-53.
- Descriptor: reversible lanes.
- 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.
- 3.03 HUTCHINSON, JOHN W., KENNEDY, THOMAS W., AND SURMAN, HUGO E. "History of Median Development in Illinois." Highway Research Record 105, 1966, pp. 50-84.
- Descriptor: median design.
- The history of median development in Illinois was compiled as part of a study aimed at the determination of desirable widths and cross-sections for medians of divided highways. This report is intended to provide a summary of the thoughts involved in the development of what are currently believed to be acceptable median designs for the various sets of conditions that have been encountered throughout the state. It presents some indication of the extent to which various types of medians are believed to have provided the intended traffic safety and service benefits, but deals primarily with the reasons behind the adoption or elimination of specific median design features.
- 3.04 PUSHKAREV, BORIS. "A Strategy for Improving Highway Appearance." Paper presented at the 51st Annual Michigan Highway Conference, MICHIGAN CONTRACTOR AND BUILDER, Vol. 60, No. 1, April 16, 1966, pp. 49, 56, 58, 59. Highway Research Abstracts, Vol. 36, No. 10, October 1966, p. 13.
- Descriptor: aesthetics
- This report deals with the necessity of providing a pleasing view to the driver. This must be done mostly in the construction of the freeway itself.
- 3.05 LAO, VINCENT L. "Vertical Curve Plotting With Circular Templates." Journal of Highway Division ASCE, Vol. 90, No. HW 2, Proc. Paper 3998, August 1964, pp. 1-7. Highway Research Abstracts, Vol. 34, No. 11, Nov. 1964, p. 22.
- Descriptor: vertical curves.
- This report deals with the discussion of an empirical equation developed to facilitate the use of existing circular curve templates for plotting vertical curves.
- 3.06 MCALPIN, GEORGE W., GRAHAM, MALCOLM D., BURNETT, WILLIAM C., AND MCHENRY, RAYMOND R. "Development of an Analytical Procedure for Prediction of Highway Barrier Performance." Highway Research Record 83, 1965, pp. 188-200.
- Descriptors: median barriers; guard rails; mathematical models.
- This paper reports on the testing of median barriers, guard rails, and bridge rails to gain a fuller understanding of the forces involved between vehicle and barrier during collision. This work has resulted in the development of mathematical models for predicting the performance of current and proposed barrier designs. Barrier performance as predicted by computer solution of the mathematical model has been verified by subsequent full-scale crash tests.
- 3.07 MORRIS, S.S. "South Africa's Approach to Urban Traffic and Freeways." Traffic Quarterly, Vol. XVIII, No. 2, 1964, pp. 202-218.
- Descriptors: highway planning; impact.
- This paper discusses the freeway system of the three major South African cities, the development of inter-city freeways, and the general results of the use of the freeway system.
- 3.08 ROBERTS, P.O. AND SUHRBIER, J.H. "Highway Location Analysis: An Example Problem." Mass. Institute of Technology Research Rept. R62-40, April 1963. Highway Research Abstract, Vol. 34, No. 2, Febr. 1964, p. 11.
- Descriptors: location study; economic impact.
- This report presents the results of a location study and economic analysis of a short segment of new interstate highway in eastern Massachusetts.
- 3.09 THARP, KENNETH J. AND HARR, MILTON E. "A Quantitative Evaluation of the Geometric Aspects of Highways." Highway Research Record 83, 1965, pp. 29-44.
- Descriptors: traffic flow-models; geometrics.
- This study is an investigation of a quantitative measure of the resistance to the flow of traffic as offered by geometric highway features. Under consideration is a mechanistic model resulting from the

postulate that traffic reacts to a motivating pressure potential which in turn reflects the behavior of the traffic traversing a particular section of highway. When solved, the governing differential equation yields a parameter called the modulus of geometric aspects. This parameter is a measure of the ease with which traffic traverses the given roadway section.

To evaluate the developed model and determine the reasonableness of the modulus of geometric aspects, a detailed study was undertaken of vehicle speeds on an actual highway curve. Statistical methods were used to analyze the data and to determine the goodness of fit of the theoretical and observed speed distributions.

- 3.10 WALKER, LARRY G. "Computer Program for Highway Design." Texas Highways, Vol. 13, No. 1. Jan. 1966, pp. 18-22. Highway Research Abstract, Vol. 36, No. 6, June 1966, p. 9.

Descriptor: computerized design.

In this article the geometry package is described.

B. INTERCHANGE TYPES, DESIGN, AND LOCATION

- 3.11 ALEXANDER, CHRISTOPHER AND MANHEIM, MARVIN L. "The Design of Highway Interchanges: An Example of a General Method for Analyzing Engineering Design Problems." Highway Research Record 83, 1965, pp. 48-87.

Descriptor: interchange design - methodology.

This interim report describes the application of a set-theoretic decision method, to the problem of highway interchange design. This paper introduces the method, and describes the shortcomings of the AASHO manual as a design program. It also describes the preparation of the interchange problem for analysis and discusses the results of preliminary analysis of the problem. A program for the design of a highway interchange is presented and some partial solution attempts are described.

- 3.12 DRAKE, JAMES. "English Motorway Construction Planned for Traffic Distribution." Traffic Engineering, Vol. 36, No. 2, Nov. 1965, pp. 17-20 and 47.

Descriptors: interchange; accidents.

This report deals with the English Motorways and the interchange designs that make travel safer with fewer accidents.

- 3.13 GERN, R.C. AND JOYNER, H.R. "Crossroute Access Design in Interchange Areas." Highway Research Record 59, 1964, pp. 1-8.

Descriptors: interchange-design situations; land use control; congestion.

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.

- 3.14 HONG, H. "Some Aspects of Interchange Design." Traffic Engineering, Vol. 36, No. 10, July 1966, pp. 26-30.

Descriptor: interchange design.

In this paper some of the observations and new thoughts on the geometric design of an interchange and its immediate vicinity on the Milwaukee County Freeway Systems are discussed, with a hope that some contribution may be made toward better design of freeway systems in the future.

- 3.15 LEHMANN, LAWRENCE L. "Criteria for Contour Gradients and Drainage Plans for Interchanges and Other Special Areas - A Total Design Concept." Highway Research Record 93, 1965, pp. 44-48.

Descriptors: plans-contour; drainage.

This paper describes the proper method for presenting plans dealing with contours and drainage.

- 3.16 PINNELL, C., BARNETT, J.D., HAYNES, J., AND RADKE, M. "Guide to the Selection of Non-directional Interchanges." TTI Final Report, November 1963, 43 pp.

Descriptors: freeway entrance and exit ramps; diamond interchanges; cloverleaf interchanges; capacity; cost; signalization.

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.

- 3.17 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 Record 172, 1967, pp. 54-93.

Descriptor: interchanges - optimum spacing.

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.

- 3.18 WILSON, SAMMY L. AND RADKE, MILTON L. "Considerations for the Installation of U-Turns at Freeway Interchanges." T.T.I. Research Report 24-18, October 1966, 67 pp.

Descriptor: interchange - U-turns.

This report will deal mainly with the diamond-type interchange. Special emphasis has been given to the study of certain movements through these facilities, namely the U-turn maneuver in order to determine the effect of these movements upon the operating efficiency of the interchange. It was the objective of this study to investigate the U-turn movement of frontage road traffic in order to determine its effect on the delay produced at signalized intersections and to determine minimum design criteria required to facilitate this movement at freeway interchanges. The location of these study sites are shown.

geometric considerations which was conducted to investigate the use of diamond-type, X-type, and stacked-type freeway ramp configurations. Conclusions are reached on the most desirable arrangement and configuration of freeway ramps. Interchange spacing is considered in relation to desired ramp configurations. Two types of interchange spacing are presented.

D. FREWAY AND INTERCHANGE EXAMPLES

- 3.21 CANO, JOSE LUIS. "Freeways in Lima, Peru." Traffic Engineering, Vol. 36, No. 11, August 1966, pp. 54-57.

Descriptor: freeway.

This is an article discussing the freeways in Lima, Peru, including what they have accomplished and their present projects.

- 3.22 DUNIVAN, ROBERT E. "Golden Glades Interchange Nears Completion Date." Traffic Engineering, No. 12, Sept. 1964, pp. 12-15.

Descriptor: interchange.

This article discusses the Golden Glades Interchange, one of the largest in the nation, which is nearing completion after two years. It covers more than 215 acres of land, includes 13 highway and two railroad bridge structures, and provides access between eight major approach routes.

C. RAMP DESIGN

- 3.19 TIPTON, WILLIAM EARL. "An Investigation of Factors Affecting the Design Location of Freeway Ramps." A Thesis submitted to Texas A&M University, August 1965.

Descriptors: ramps - location, layout, spacing; gap availability; drivers' desires.

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.

- 3.20 TIPTON, WILLIAM EARL, AND PINNELL, CHARLES. "An Investigation of Factors Affecting the Design Location of Freeway Ramps." Presented as a paper to the 45th Annual Meeting of the Highway Research Board, January 17-21, 1966. Highway Research Record 152, 1967, pp. 1-35.

Descriptors: ramps - location, layout, spacing; gap availability; drivers' desires.

This article reports on a study of driver desires, freeway gap availability, and

SECTION 1
OPERATIONS

A. FREEWAY

1. GENERAL

- 4.01 ATHOL, PATRICK J. "Interdependence of Certain Operational Characteristics Within A Moving Traffic Stream." Presented as a paper at the 43rd Annual Meeting of the Highway Research Board, January 13-17, 1964. Highway Research Record No. 72, 1965, pp. 58-87.

Descriptors: lane occupancy; congestion.

In this paper, lane occupancy, a point measurement comparable with concentration, was compared to volume and speed and the interrelationship was recorded. Lane occupancy has practical advantages in representing the degree of concentration existing within a moving traffic stream. Aerial photographs of the study area were used to compare occupancy and aerial density of traffic. Congestion of traffic is discussed with some consideration given to a possible definition of congestion.

- 4.02 BETZ, MATHEW J. AND SUPERSAD, JARNIE, N. "Traffic and Staggered Working Hours." Traffic Quarterly, Vol. XIX, No. 2, April 1965, pp. 188-203.

Descriptors: staggered working hours; congestion.

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.

- 4.03 DREW, DONALD R. "Deterministic Aspects of Freeway Operations and Control." TTI Research Report 24-4, June 1965. 53 pp.

Descriptors: speed; density; volume; freeway operations.

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.

- 4.04 DREW, DONALD R. "A Study of Freeway Traffic Congestion." A Dissertation submitted to the Texas A&M University Graduate College, May 1964, 160 pp.

Descriptor: freeway traffic congestion.

This dissertation represents an attempt to describe the phenomena of freeway traffic congestion quantitatively, and to determine those characteristics of traffic flow that are capable of automatic detection and control. Application of both the deterministic and stochastic approaches to traffic operations, freeway surveillance, and geometric evaluation and design are suggested.

- 4.05 DREW, D.R. "Theoretical Approaches to the Study and Control of Freeway Congestion." TTI Research Project 24-1, January 1964, 27 pp.

Descriptors: congestion; capacity; speed; control.

This article discusses the possibility of reducing freeway congestion in the form of controls on the freeway and the metering of inputs on the freeway. The problems of freeway operation and control are described by deterministic mathematical models. By showing a generalization and comparison of macroscopic and microscopic models of traffic flow the applicability of these deterministic models to freeway traffic is readily seen. Such macroscopic parameters as capacity and the optimum speed provide good indices of congestion and bases for control.

The need for a more sensitive indicator of congestion than density led to the formulation of the moving queues model. The expected number of vehicles per moving queue provides a quantitative index of congestion. The congestion index developed offers more than a subjective means of evaluating freeway performance.

- 4.06 "Eleven States Join Michigan in First Experiment of Electronic Traffic Control," Michigan Contractor and Builder, Vol. 57, No. 32, p. 1, Nov. 9, 1963. Highway Research Abstracts, Vol. 34, No. 4, April 1964, p. 12.

Descriptors: experimentation; electronic control; freeway traffic.

This paper discusses the eleven states which have joined Michigan in the operation of the nation's first experiment in the electronic control of freeway traffic. A 3.2-mi section of the John Lodge Freeway in Detroit will become a national proving ground for research by the eleven states. Comprehensive studies of freeway traffic and driver behavior and their effects on traffic flow will be completed and new studies will be started to evaluate lane, speed and ramp controls.

- 4.07 GERVAIS, EDWARD F. "Optimization of Freeway Traffic by Ramp Control." Presented as a paper at the 43rd Annual Meeting of the Highway Research Board, January 13-17, 1964. Highway Research Record 59, 1964, pp. 104-118.

Descriptors: volume; speed; lane occupancy.

This paper deals in large part with the installation of a freeway traffic control system that consists of variable speed signs and lane signals placed at spaced intervals. Studies included the gathering of volumes, speed, and lane occupancy by individual lanes and their relationship with each other have shown that the freeway handles the best traffic volumes when speeds are in the higher ranges. The paper shows the volumes, speeds, lane occupancy percentages, etc. . . .

- 4.08 HAYNES, JOHN J. "Some Considerations of Vehicular Density on Urban Freeways." Texas Transportation Institute and Texas Highway Dept., Cooperative Research, Res. Rept. 24-6 (Project 2-8-61-24) April 1965, 61 pp. Highway Research Record 21, 1965, pp. 59-80.

Descriptors: freeway traffic control; density; aerial photography.

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.

- 4.09 LYNCH, FRANK L. AND KRESE C.J. "Restoring Freeway Operation After Traffic Accidents." TTI Bulletin No. 28, pp. 5-18.

Descriptors: traffic flow; accident investigation; freeway operation.

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

- 4.10 MAY, ADOLF D. JR. "Improving Network Operations with Freeway Ramp Control." Presented as a paper at the 43rd Annual Meeting of the Highway Research Board, January 13-17, 1964.

Descriptors: network operations; ramp control.

This paper describes the planning, conduct and evaluation of a series of experiments with freeway ramp control undertaken for the purpose of improving network operations. The development of the control plan included: identification of the critical section; determination of time and degree of control; estimation of the redistribution of traffic; and re-evaluation of system operations. The effect of the network of the ramp control was evaluated on the basis of vehicle minutes, and vehicle miles of travel for each link, route, and for the total net-

work. The results indicate that travel time on a network basis was reduced by freeway ramp control.

- 4.11 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.

Descriptors: ramp control; operation.

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 present traffic conditions instead of being based on what the freeway traffic conditions were on a typical day several months before.

In addition, the traffic operation after termination of the control study was also studied and these results are also presented.

- 4.12 PINNELL, CHARLES, DREW, DONALD R., MCCASLAND, WILLIAM R., AND WATTLEWORTH, JOSEPH A. "Inbound Gulf Freeway Ramp Control Study I." TTI Research Report 24-10, December 1964, 57 pp.

Descriptors: ramp control; demand-capacity mode.

This study was limited to the entrance ramps on the inbound Gulf Freeway from Wayside Drive to the downtown distribution system during the morning peak period. These and later studies were used to evaluate the effect of the ramp control operation. The controls which were tested were fixed-time controls. The approach or philosophy used in the development of this plan was to estimate the demand rate and capacity flow rate at each entrance ramp merging section from Wayside Drive to Scott Street and to control each entrance ramp in this section as severely as needed to keep the demand less than or equal to capacity.

- 4.13 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.

Descriptors: surveillance; control.

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 and an evaluation of the control action and probable future research in this area is summarized.

- 4.14 SANFERRRE, GARY LEE. "An Investigation of the Feasibility of Improving Freeway Operation by Staggering Working Hours." TTI Research Report 24-16, January 1967, 52 pp.

Descriptor: traffic control - staggered working hours.

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 time and thereby reducing the congestion on the morning peak period operation of the Gulf Freeway. The author views the concept favorably.

- 4.15 WATTLEWORTH, JOSEPH A. "Peak Period Analysis and Control of a Freeway System." Presented as a paper to the 45th Annual Meeting of the Highway Research Board, Jan. 17-21, 1966. Highway Research Record 157, 1967, pp. 1-21. Similar report by Wattleworth, J.A., TTI Research Report 24-15, 1965, 23 pp.

Descriptors: ramp metering - demand - capacity mode; linear-programming model.

This paper presents ideas on an optimization approach to the problem of freeway ramp control during peak periods. The variable to be optimized, in this case maximized, is the total output rate of the critical portion of the freeway system; 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 proposed system, each entrance ramp is metered at a rate which maintains the total merging flow rate at or below a rate set by a central computer which 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 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 existing conditions.

- 4.16 WATTLEWORTH, J.A. "System Demand-Capacity Analysis of the Inbound Gulf Freeway." TTI Research Report 24-8, October 1964, 60 pp.

Descriptors: input-output counts; fixed time control; estimated demand.

This article investigates the worth of input-output counts as a method of predicting congestion. The author feels that when the counts at each input to the freeway are combined with origin-destination data it is possible to estimate the demand rate at each critical bottleneck. The 5 minute demand rates are then com-

pared to capacity and from this determined what fixed time control measures to initiate.

- 4.17 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.

Descriptors: freeway system control - criteria; input-output analysis; linear programming model.

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.

- 4.18 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.

Descriptors: merging control equipment-operation; evaluation.

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.

- 4.19 WILSHIRE, ROY L., AND KEESE, C.J. "Effects of Traffic Accidents on Freeway Operation." TTI Bulletin No. 22, April 1963, pp. 3-13.

Descriptors: freeway accidents - traffic control; accident reporting; level of service.

This report was designed to study the effects of traffic accidents on freeway operation in the interest of improving the level of service, to analyze and improve traffic control methods employed during accident investigation, and to promote better freeway accident reporting and greater interest among investigation personnel so that complete accident information suitable for engineering analyses could be provided.

B. INTERCHANGE1. GENERAL

- 4.20 BARNETT, JAMES DAVID III. "A Comparative Study of the Conventional Diamond and Cloverleaf Interchanges with Respect to Ramp Capacity and Vehicular Delay." A Thesis submitted to the Graduate School of the Texas A&M University, August 1963, 65 pp.

Descriptors: interchanges - diamond, cloverleaf; ramp capacity; delay.

This research lists two specific objectives; to investigate the total time required to make the left turn maneuver from a point outside the interchange on the arterial to a point where merge had been made with the freeway traffic, for both the conventional cloverleaf interchange.

- 4.21 CAPELLE, DONALD G. AND PINNELL, CHARLES. "Capacity Study of Signalized Diamond Interchanges" Reprint 21, Highway Research Board Bulletin 291, 1961. Similar report, TTI Research Report 1-62.

Descriptors: signalized diamond interchanges - design capacity, operation.

This paper presents a portion of the results from a research project on freeway ramps and interchanges. This study was designed to obtain traffic performance data which would have useful application in evaluating the capacity of signalized diamond interchanges. The field data were gathered through the use of time motion pictures which furnished a complete and simultaneous record of the traffic operations occurring in the intersections that were studied. The analysis of the study produced some significant results and provides the designer with current operational characteristics of vehicles at signalized diamond interchanges. Design procedures for diamond interchanges are presented in this report.

- 4.22 MCCASLAND, WILLIAM R. "Traffic Characteristics of the Freeway Interchange Traffic of the Inbound Gulf Freeway." TTI Research Report 24-7, October 1964, 61 pp.

Descriptors: freeway travel patterns; zone of influence.

A discussion of origin destination studies made on the Gulf Freeway, giving a breakdown of the travel patterns of interchange traffic as to trip lengths and routes employed to reach the freeway, as well as establishing the zone of influence of the facility is presented.

- 4.23 MCDERMOTT, JOSEPH M. AND MCLEAN, CHARLES. "Improving Traffic Flow at Transfer Roadways on Collector-Distributor Type Expressways." Presented as a paper at the 43rd Annual Meeting of the Highway Research Board, January 13-17, 1964. Highway Research Record 59, 1964, pp. 83-103.

Descriptors: collector-distributor expressway - operation, transfer roadways; signing; marking.

This paper discusses Chicago's Dan Ryan Expressway through a rather comprehensive study to ascertain the efficiency of its operation, particularly at transfer roadways. Time-lapse ground photography was used at typical locations and an analysis was made of volumes, speeds, distributions, vehicle classifications, etc. . . . The effects of pavement marking and signs on traffic operations at transfer roadways are also discussed.

2. RAMPS

- 4.24 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.

Descriptors: traffic behavior - headway groupings; ramp control.

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 tape with headways recorded to 0.01 sec. The analysis is conducted on a digital computer.

- 4.25 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.

Descriptors: merging control system; merging maneuver; congestion.

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 discuss the application of the control function in the merging control of freeway on-ramps.

- 4.26 BUHR, JOHANN H. "Traffic Interaction in the Freeway Merging Process." TTI Report 430-5, 93 pp.

Descriptors: time headways; gap stability; lane changing; gap acceptance.

This paper deals primarily with the behavior of time headways between vehicles 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.

- 4.27 "California Tries to Stop Wrong-Way Entries." Western Construction News, Vol. 40, No. 7, July 1965, p. 92. Highway Research Abstract Vol. 36, No. 3, March 1966, p. 8.

Descriptor: signing - wrong-way entries.

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

- 4.28 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.

Descriptors: off-ramps - capacity, effect on freeway operation.

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.

- 4.29 COVAULT, DONALD O. AND KIRK, ROBERT C. "Influence of Off-Ramp Spacing on Traffic Flow Characteristics on the Atlanta Freeway and Arterial Street System." Paper presented at the 43rd Annual Meeting of the Highway Research Board, January 13-17, 1964. Highway Research Record 59, 1964, pp. 39-52.

Descriptors: off-ramp spacing; speed and delay studies.

The purpose of this study was to determine the influence of off-ramp spacing on the operational characteristics of the Atlanta Freeway System and the city streets influenced by the freeway. Speed and delay studies were made on the freeways and surface streets during certain ramp closures and during normal operation of the Freeway. It was found that off-ramps leading to the central business district of a city should be spaced as close together as possible consistent with design factors and the ability of the surface streets in the vicinity of the off-ramp to accommodate the traffic flow from the ramp.

- 4.30 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 Research Record 208, 1967, pp. 1-36. Similar study in TTI Research Report 430-2.

Descriptors: traffic flow distributions; freeway merging - models, parameters; gap acceptance.

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 of 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 character-

istics. 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. Through the application of "individual record probit analyses" simple, statistically significant relationships between the percent gap acceptance and gap size are established.

- 4.31 DREW, DONALD R., WATTLEWORTH, JOSEPH A., BUHR, JOHANN H., AND WILLIAMS, THOMAS G. "Gap Acceptance and Traffic Interaction in the Freeway Merging Process." TTI Final Report, 115 pp.

Descriptors: freeway merging; applications of research.

This is the final report on extensive research into the freeway merging process conducted by the Texas Transportation Institute and sponsored by the U.S. Bureau of Public Roads. It summarizes and incorporates in a single publication, the techniques, procedures and findings to the solution of practical problems. The various aspects of the research are discussed in greater detail in the series of Project Reports, 430-1, through 430-7.

- 4.32 EDWARDS, FRED HUNTLEY. "A Study of Driver Behavior on Freeway Entrance Ramps." A Thesis submitted to the Graduate School of the Texas A&M University, August 1961, 47 pp.

Descriptor: entrance ramp - driver behavior.

The objectives of the driver behavior research were two-fold: (1) develop a method for studying driver behavior on freeway entrance ramps; (2) Correlate driver behavior with vehicle maneuvers and entrance ramp design. It was believed that by applying the study technique to two ramps, the feasibility of this approach to design evaluation could be demonstrated. The two ramps selected for the study were one in Houston and one in San Antonio. The results of the study indicated that the manner in which a driver evaluated freeway traffic conditions and the location on the ramp approach at which the evaluation was made affected not only the operation of the ramp but the operation of the freeway as well.

- 4.33 EVANS, DAVID H. AND HERMAN, ROBERT. "The Highway Merging and Queuing Problem." Operations Research, Special Transportation Science Issue, Vol. 12, No. 4, pp. 832-857, Nov.-Dec. 1964. Highway Research Abstracts, Vol. 35, No. 6, June 1965, p. 5.

Descriptors: queuing models; merging.

A study of several aspects of the theory of car queues is presented. Several particular cases are presented. An expression for the generating function of the steady-state distribution and the waiting time distribution is derived. The critical input to the side road is determined. Re-

- sults are presented of a study by simulation techniques for the analysis of traffic queueing models.
- 4.34 "Exit-Ramps, Wrong-Way Traffic Problems for U.S." Traffic Engineering, Vol. 35, No. 4, January 1965, pp. 24-27.
- Descriptors: wrong-way traffic problem - magnitude, remedy.
- Fifteen percent of the States felt this was a problem and considered it to be serious enough to warrant rather extensive studies in an effort to assess its magnitude and to determine what steps might be taken to remedy it.
- 4.35 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.
- Descriptors: expressway-highway-exit ramp system; intersection control; minimum delay.
- 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.
- 4.36 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.
- Descriptors: capacity; ramps; weaving areas.
- 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.
- One equation was derived to enable forecasting of lane volume distributions up-stream from a diverging major fork where three lanes split into two, two-lane roadways.
- Preliminary results are given of on-ramp vehicle freeway lane usage studies made on the Ford Freeway in Detroit.
- 4.37 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.
- Descriptors: off-ramps - wrong-way drivers; signing.
- 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.
- 4.38 JEWELL, W. S. "Forced Merging in Traffic." Operations Research Center 64 1RR. Jan. 15, 1964, Available from: Clearinghouse, Springfield, Virginia. AD 601 258. Highway Research Abstracts, Vol. 34, No. 11, November 1964, p. 3.
- Descriptors: forced entry - renewal process, accident potential, main stream headways.
- A vehicle waiting at an intersection of a major road forces an entry into the main-stream traffic by requiring the oncoming traffic to slow down. Assuming that the mainstream traffic can be described as a renewal process, the paper examines the resulting disturbance which the forced entry creates in the main stream. After showing that it is formally equivalent to a busy period problem explicit results are obtained in the case of Poisson traffic. It is shown that there is a minimal main-stream headway which should be forced to maximize the rate of entry into the major road by many waiting vehicles. Finally, two measures of accident potential are discussed.
- 4.39 KEESE, C.J. AND SCHLEIDER, R.H. "The Correlation of Design and Operational Characteristics of Expressways in Texas." TTI Progress Report, January 1957, pp. 1-39.
- Descriptors: ramp operation - open vs closed entrance ramps; motion picture survey technique; median barrier - vehicle placement.

This article discusses the accuracy of the motion picture type survey used in obtaining necessary data for studying traffic operational characteristics. Speed and volume data were related in order to compare open and closed entrance ramp operation on the Houston Gulf Freeway and the Dallas Central Expressway. The effect of a median barrier fence and opposing traffic on vehicle placement is also analyzed.

- 4.40 LIPSCOMB, JOHN NAYLOR. "The Effects of Ramps on the Lateral Distribution of Vehicles on a Six-Lane Freeway." A Thesis, Texas A&M University, August 1962, 61 pp.

Descriptors: lane distribution - effect of ramp spacing; volume; arrangement.

This research has been conducted to determine the effect of ramps on the lane used or lane distribution of a six-lane freeway. The effects of adjacent ramp arrangements, ramp spacing, and ramp volume have been investigated. A design procedure also has been devised. In the first phase of the research, seven studies conducted on the Houston Gulf Freeway and one study on the Dallas North Central Expressway were used to develop the distribution relationships. In the second phase of the analysis, the relationships developed in phase one were applied to the data observed at 41 other sites, and the differences between the expected and the observed percent in lane 1 were analyzed. Five conclusions were drawn from this research each dealing with the effects different situations, such as exit ramps, adjacent entrance and exit ramps, etc., have on lane distribution.

- 4.41 MAY, ADOLF D. "Experimentation with Manual and Automatic Ramp Control." Highway Research Record 59, 1964, pp. 9-38.

Descriptors: ramp control; network operations.

This paper describes the planning, conduct and evaluation of a series of experiments with freeway ramp control undertaken for the purpose of improving network operations.

The development of the control plan included the identification of the critical section, determination of the period of time and degree of control, estimation of the redistribution of traffic, and re-evaluation of the systems operations. A comprehensive set of measurements was obtained for the network, including expressways and major arterials, for three weeks without control and for three weeks with freeway ramp control. The ramp control consisted of partially closing one on-ramp and metering traffic at a second on-ramp. The effect on the network of the freeway ramp control was evaluated on the basis of vehicle-minutes and vehicle miles of travel for each link, route, and for the total network. The results indicate that travel time on a network basis was reduced by freeway ramp control.

- 4.42 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.

Descriptors: ramp metering; gap availability; gap acceptance; mathematical distributions.

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.

- 4.43 MCDEERMOTT, 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.

Descriptors: ramp metering; computer analysis; surveillance detection system.

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.

- 4.44 "Ramp Metering Tested on Congress Street Expressway." Cook County Highways, Vol. 11, No. 4, pp. 4-5, Sept. 1963. Highway Research Abstracts, Vol. 34, No. 3, March 1964, p. 10.

Descriptors: ramp metering; network information and control system.

The immediate objective of the surveillance project as stated by the director, is to "develop, to operate and to evaluate a pilot network information and control system to reduce travel time and to increase traffic flow. Successful progress could lead eventually to a centralized information and control center for the entire Chicago Metropolitan expressway and major street network systems."

- 4.45 REDDY, M. SKIRAMULU. "Quantitative Evaluation of the Effect of Merging Vehicles on Freeway Operation." A Dissertation submitted to the Graduate College of the Texas A&M University, January 1966, 137 pp.

Descriptors: freeway merging model; effects of ramp geometrics; entrance ramp design.

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 operation, and (4) to suggest a method for improving the design of entrance ramps.

- 4.46 TIPTON, W.E., CARVELL, J.D., PINNELL, C. "Effects of Off-Ramps on Freeway Operation." TTI Research Report 59-4, October 1965, pp. 1-129.

Descriptors: off-ramps - effect on freeway operations and trip generation, capacity, location, configuration; acceleration noise; deceleration distance; access control.

This report, in three parts, considers the problem of the effects of off-ramps on freeway operation with emphasis on several factors. Among these being (1) deceleration distance, with its relation to traffic flow on the facility and shock waves created; (2) off-ramp capacity with regard to its three critical points, and the relationship of both to acceleration noise. The second part of the report contains (1) a study of the effect of off-ramps on short-trip generation and their effect on the freeway as a long trip facility; (2) the effect of weaving maneuvers and their relation to off-ramp frequency; and (3) access control with its relation to wrong-way entrances onto the facility. The third part concerns the effect of off-ramps on access provision with emphasis on ramp configuration and location.

- 4.47 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. Similar article in TTI Research Report 430-3, 1967.

Descriptors: entrance ramps - design, geometrics effecting freeway operation.

This article reports on a study made of entrance ramps having a wide 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 point, the accepted gap number, and the distribution of points of entry onto the freeway. General conclusions regarding entrance ramp design are presented.

- 4.48 WORRAL, R.D., BUHR, J.H., BERRY, D.S., DRAKE, J.S., AND SOLTMAN, T.J. "Operational Characteristics of Left-Hand Entrance and Exit Ramps on Urban Freeways." Presented at the 44th Meeting of the Highway Research Board,

January 11-15, 1965. Highway Research Record 99, 1965, pp. 244-273.

Descriptors: left-hand entrance and exit ramps - accident rates; operational efficiency.

In this study is included a look at the operational characteristics of left-hand as opposed to right-hand entrance ramps, an analysis of traffic behavior along a 2-mile section of freeway containing two internal diamond interchanges, and a comparative study of accident rates of a sample of right and left-hand ramps. Brief descriptions are given of study locations and techniques, together with a detailed discussion of major results. A number of conclusions are drawn concerning the operational efficiency, relative safety and general suitability of left-hand ramps.

- 4.49 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.

Descriptors: gaps; ramps; computer analysis; merging behavior; gap acceptance; bibliography; analytical techniques.

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.

3. WEAVING SECTIONS

- 4.50 HESS, JOSEPH W. "Ramp-Freeway Terminal Operation as Related to Freeway Lane Volume Distribution and Adjacent Ramp Influence." Highway Research Record 99, 1965, pp. 81-116.

Descriptors: capacity; ramps; weaving areas.

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 mean traffic stream at the ramp nose. The contribution of the deceleration lane to capacity and smooth operation is stressed.

One equation was derived to enable forecasting of lane volume distributions up-stream from a diverging major fork where three lanes split into two, two-lane roadways.

Preliminary results are given of on-ramp vehicle freeway lane usage studies made on the Ford Freeway in Detroit.

- 4.51 KNOX, D.W. "Merging and Weaving Operations in Traffic." Australian Road Research, Journal of Australian Road Research Board, Vol. 2, No. 2, Dec. 1964, pp. 10-20. Highway Research Abstract, Vol. 35, No. 5, May 1965, pp. 1-2.

Descriptors: weaving; merging; photography.

Studies are described of merging and weaving characteristics for motor cars and similar small vehicles operating under Australian conditions. Photographic observations were made at two sites on the Cahill Expressway in Sydney. Analysis of individual vehicles, shown in enlarged pictures, enabled the measurement of speed

lateral movement, gaps accepted, and time and length to complete a merge or weave.

C. TUNNELS

- 4.52 DAWSON, ROBERT F., AND MICHAEL, HAROLD L. "Analysis of On-Ramp Capacities by Monte Carlo Simulation." Highway Research Record 118, 1966, pp. 1-20.

Descriptors: on-ramp capacity; Monte Carlo simulation.

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, high-volume 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.

- 4.53 DUCKSTEIN, LUCIEN. "Control of Traffic in Tunnels to Maximize Flow." Presented to the 45th Annual Meeting of the Highway Research Board, Jan. 17-21, 1966. Highway Research Record 154, 1967, pp. 1-23.

Descriptor: traffic flow - control system.

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

- 4.54 RADKE, MILTON L., "Evaluation of the Television Surveillance System for the Baytown-LaPorte Tunnel." TTI Research Report 47-1, February 1966, 40 pp.

Descriptor: television surveillance.

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.

- 4.55 REID, ANN S.H. "Road Tunnels More Than 500 Feet Long." Britain Road Res. Lab., Road Res. Technical Paper No. 78, 1965, 68 pp. Highway Research Abstract, Vol. 36, No. 5, May 1966, p. 13.

Descriptors: tunnel ventilation; bibliography.

A bibliography on the ventilation of road tunnels is included and a list of the world's road tunnels.

D. CAPACITY

- 4.56 DAWSON, ROBERT F. AND MICHAEL, HAROLD L. "Analysis of On-Ramp Capacities by Monte Carlo Simulation." Highway Research Record 118, 1966, pp. 1-20.

Descriptors: on-ramp capacity; Monte Carlo simulation.

In recent years thousand 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 high-speed, high-volume 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.

- 4.57 DREW, D.R. "Gap Acceptance Characteristics for Ramp-Freeway Surveillance and Control." TTI Research Report 24-12, July 1965, 43 pp.

Descriptors: gap acceptance; merging delay; critical gap distribution.

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. The critical gap for stopped 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.

A distribution of critical gaps was found and fitted to a gamma distribution. Merging delay values calculated using the distribution were shown to be higher than those calculated assuming that all drivers have the same critical gap. The calculated values were also compared to observed merging delays.

- 4.58 DREW, DONALD R., BUHR, JOHANN H., AND WHITSON, ROBERT H. "The Determination of Merging Capacity and Its Application to Freeway Design and Control." TTI Report 430-4, 1967.

Descriptors: merging capacity; critical gap; level service; design; control.

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 of gaps in the freeway shoulder lane. The service volumes suggested are developed from considerations of the ramp junction as a queueing 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 angle of convergence.

Relationships are also presented of estimating the entire gap acceptance characteristic from these two geometric features.

The paper proceeds to discuss in detail the application of the developed merging parameters in freeway design and control.

- 4.59 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.

Descriptors: volume, demand; capacity; freeway operations and design; level of service.

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.

- 4.60 HESS, JOSEPH W. "Ramp-Freeway Terminal Operation as Related to Freeway Lane Volume Distribution and Adjacent Ramp Influence." Highway Research Record 99, 1965, pp. 81-116.

Descriptors: capacity; ramps; weaving areas.

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.

One equation was derived to enable forecasting of lane volume distributions upstream from a diverging major fork where three lanes split into two, two-lane roadways.

Preliminary results are given of on-ramp vehicle freeway lane usage studies made on the Ford Freeway in Detroit.

- 4.61 HESS, JOSEPH W. "Capacities and Characteristics of Ramp Freeway Connections: II." Presented at the 44th Annual Meeting of the Highway Research Board, Jan. 11-15, 1965.

Descriptors: ramps - capacity, combinations, design.

This paper completes the analysis of the data collected during the nationwide freeway ramp capacity study. It also contains an analysis of considerable data collected subsequently, particularly that collected in the 1963 weaving study conducted by a crew of Bureau of Public Roads junior engineers. Nomographic solutions present the various combinations of ramps possible and the design necessary to prevent overloading of critical sections along the freeway.

- 4.62 HODKINS, EDMUND A. "Effect of Buses on Freeway Capacity." Highway Research Record 59, 1964, pp. 66-82.

Descriptors: capacity; bus lanes; passenger car equivalents.

This paper reports on a study to measure the speeds and the spacing between buses on freeways and to determine the passenger car equivalent of buses on such roads, thus permitting determination of the theoretical capacity of the separate all-bus lane on a freeway. It was felt that by studying a combination of speed-volume data and "cluster" data, it would

be possible to develop capacity values as well as to determine the effect of buses on the traffic stream. Conclusions are reached as to when it would be desirable to designate separate lanes as bus lanes.

- 4.63 KEESE, C.J., PINWELL, 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.

Descriptors: signalization; surveillance; control; design; intersections; lane distribution; level of service.

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

Discussion includes signalized intersection design as well as freeway operation.

- 4.64 MUELLER, EDWARD A. "A New Look at Highway Capacity." Traffic Quarterly, Vol. XX, No. 3, July 1966, pp. 322-346.

Descriptor: highway capacity.

This article presents an annotation of the 1965 Highway Capacity Manual, published by the Highway Research Board of the National Academy of Sciences - National Research Council.

- 4.65 NEWLAN, LEONARD AND MOSKOWITZ, KARL. "Effect of Grades on Service Volume." Highway Research Record 99, 1965, pp. 224-243.

Descriptors: trucks; capacity; grades; rural roads.

The problem of determining effects of trucks or any slow-moving vehicles on the operating characteristics of a section of multilane road is discussed. The action of trucks in reducing the service volume of a road is described and is related to the number of trucks, speed of trucks (steepness of grade), and length of grade. Relationships between these factors are developed and presented in the form of a proposed design chart for determining equal service volumes which would be suitable for rural conditions for any combination of grade, autos, and trucks. The use of this chart in determining when additional lanes should be added and the effects of trucks on maximum capacity of a road are described.

- 4.66 SCHWAR, JOHANNES F. "Quality of Traffic Service." Traffic Quarterly, Vol. XX, No. 1, January 1966, pp. 136-146.

Descriptor: traffic service.

This article considers a proper way to define and to measure traffic services.

SECTION 5

STUDY TECHNIQUES

A. GENERAL

- 5.01 BUHR, J. H., DREW, D. R., WATTLEWORTH, J. A., AND WILLIAMS, T. G. "A Nationwide Study of Freeway Merging Operations." Presented as a paper before the 46th Annual Meeting of the Highway Research Board, Jan. 16-20, 1967. Similar study in TTI Research Report 430-1, 1967.

Descriptors: photographic technique; traffic flow parameters.

This paper introduces the research project "Gap Acceptance and Traffic Interaction in the Freeway Merging Process" which forms a part of a 4-yr. program on freeway merging undertaken by the Bureau of Public Roads. Field studies for the collection of data were performed on a nationwide basis at a number of selected entrance ramps, utilizing an aerial photographic technique. This technique, the data reduction methods, and the study sights selected are described in detail. Data editing routines and the analysis of the data for basic traffic parameters are discussed and some of these parameters used to illustrate the merging operation at each study site. The qualitative effect of various geometric elements on the operation as mirrored by the traffic parameters of volume, density, speed, and acceleration noise are discussed.

- 5.02 HAIGH, JACK A. "Statistical Digital Computer Methods For Traffic Count Analysis." Highway Research News No. 13, June 1964, pp. 45-54.

Descriptors: traffic count analysis; computers.

This paper discusses motor vehicle count analysis by digital computer in Florida. Two computer programs have been developed for count analysis, as follows: the analysis of variance program is used to (a) summarize and store traffic volume data, (b) point out statistically unacceptable data, and (c) establish volume trends; the regression analysis develops equations for correlation and projection in forecasting future traffic volumes.

- 5.03 MCCASLAND, WILLIAM R., AND WATTLEWORTH, JOSEPH A., Texas Transportation Institute, "Study Techniques for Planning Freeway Surveillance and Control." Presented at the 44th Annual Meeting of the Highway Research Board, Jan. 11-15, 1965. Also Found: Highway Research Record, 99, 1965, pp.200-223.

Descriptors: surveillance; control.

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.

- 5.04 PHILLIPS, DAVID K. AND WOOLMAN, STANLEY. "Systems Analysis Approach to Processing of Vehicular Traffic Records from Continuous-Count Stations." Highway Research News 13, June, 1964, pp. 55-69.

Descriptors: data processing; traffic counts.

The subject of this paper is the promotion of optimum utilization of automatic data processing methods in the conduct of vehicular traffic volume surveys.

- 5.05 PINNELL, CHARLES. "Gulf Freeway Surveillance and Control Project." Reprint from Traffic Quarterly, January, 1966, pp. 31-46. Similar article by Pinnell, C., TTI Research Report 24-17, July, 1966.

Descriptors: surveillance; design criteria; bibliography.

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.

A detailed bibliography is given for the serious student.

- 5.06 "Special Purpose Traffic Survey Devices," Traffic Engineering, Vol. 36, No. 5, Feb., 1966, pp. 29-41.

Descriptors: traffic survey devices - use, operation.

The article discusses in detail the use and operation of 26 different survey devices coming under the headings of vehicle mounted devices, road devices, photographic equipment and methods for traffic engineering studies, and Multiplexing and other data transmission equipment.

B. PHOTOGRAPHIC TECHNIQUES

- 5.07 BAGGOT, T. A. "Traffic Data Acquisition from Aerial Photographs by Photographic Image Processing." Highway Research Record 109, 1966, pp. 1-7.

Descriptors: photographic image processing; traffic data acquisition.

The approach to traffic data acquisition known as image processing employs electroptical scanning and conventional electronic data processing techniques to extract useful data from imagery. Basically, image processing involves three steps: digitizing, transforming, and processing. Automatic traffic data acquisition from aerial photographs by photographic image processing has been proved technically feasible. Further research and development are required, however, for an economical operating system.

- 5.08 DESROSTERS, RICHARD D. "Moving Picture Technique for Highway Signing Studies - An Investigation of its Applicability." Public Roads, Vol. 33, No. 7, pp. 143-147, April, 1965. Highway Research Abstracts, Vol. 35, No. 9, September, 1965, p. 9.

Descriptors: motion picture laboratory tests; signing studies.

Establishment of the feasibility of motion picture laboratory tests as a substitute for field research on highway signing was explored. Research related to highway signing generally has been in the form of field tests - a procedure doubly costly in collection of data and research time. Development of a suitable laboratory test, it was believed, would eliminate these problems and also permit additional control of variables that might affect the results. Comparisons of results of field and laboratory tests are reported for the mean legibility distances of signs having two, four, and six legends. Errors made by the test participants were investigated.

- 5.09 DICKINS, JUSTIN H., "New System Developed For Traffic Data Acquisition," Traffic Engineering, Vol. 35, No. 3, December, 1965, pp. 12-15.

Descriptor: photographic records of traffic operations

New techniques are instituted by the Port of New York Authority to permit simultaneous gathering of traffic statistics for extensive roadway networks and complex interchange systems. It has greater scope than conventional ground survey methods, and provides permanent photographic records of traffic operations for future reference.

- 5.10 KEESE, C. J. "Use of Traffic Studies for Evaluation of Highway Design." Presented at the Fourth World Meeting of the International Road Federation, Madrid, October 14-20, 1962.

Descriptors: motion pictures; design; accident analysis; speed studies.

The author discusses the application of the motion picture study technique in freeway design, freeway accident analyses, the effect of traffic accidents on freeway operations, and factors affecting roadway speeds.

The filming was done using a portable tower.

- 5.11 KEESE, C. J. AND SCHLEIDER, R. H. "The Correlation of Design and Operational Characteristics of Expressways in Texas." TTI Progress Report, January, 1957, 39 pp.

Descriptors: motion pictures; vehicle placement; ramp operation.

This article discusses the accuracy of the motion picture type survey used in obtaining necessary data for studying traffic operational characteristics. Speed and volume data were related in order to compare open and closed entrance ramp operation on the Houston Gulf Freeway and the Dallas Central Expressway. The effect of a median barrier fence and opposing traffic on vehicle placement is also analyzed.

- 5.12 MCCASLAND, WILLIAM R., "Comparison of Two Techniques of Aerial Photography for Application in Freeway Traffic Operations Studies." Highway Research Record No. 65, 1965, pp. 95-115. Similar report by McCasland, W. R., in TTI Research Report 3-64, pp. 1-40.

Descriptor: aerial photography.

This paper considers the role of aerial photography in freeway control. The procedures for obtaining data from aerial time-lapse photography and from aerial continuous-strip photography are presented. Economic comparisons are given.

- 5.13 TREITTERER, JOSEPH, AND TAYLOR, JAMES I. "Traffic Flow Studies by Photogrammetric Techniques." Presented as a paper to the 45th Annual Meeting of the Highway Research Board, January 17-21, 1966. Similar report in Highway Research Record No. 142, 1966, pp. 1-72.

Descriptors: traffic flow; photogrammetric techniques.

This article reports on the development of a method to measure traffic movement for testing the present theories of traffic flow. The study is concerned with vehicle spacing and speeds over short intervals. The equipment and data reduction techniques are described and samples of data are given.

C. VEHICULAR METHODS AND SPOT STUDIES

- 5.14 ALEXANDER, A. L., "Vehicle Performance Recording." *Automobile Engineer*, Vol. 53, No. 13, 1963, pp. 526-531. *Highway Research Abstracts* Vol. 34, No. 6, June, 1964, pp. 12-13.

Descriptors: moving vehicle performance parameters - measurement, recording.

In the Report, it deals with the measurement and recording of the parameters involved in studies of the performance of moving vehicles.

- 5.15 GREENSHIELDS, BRUCE, "Drivometer Determines Quality of Traffic Flow for Engineers." *Traffic Engineering*, Vol. 36, No. 2, November, 1965, pp. 28-29, 56-61.

Descriptors: traffic flow; drivometer; driver attitudes.

A main purpose of this pilot study has been to demonstrate that driver effort reflects driver attitudes - what he likes and dislikes about driving.

With this new measuring and recording device, it should be possible to set up standards of performance for evaluating traffic operations.

In turn, with these standards at hand it should be possible to improve highways and traffic control devices to achieve the desired standards of traffic flow. Better traffic flow means more economical and safer highway travel.

- 5.16 OPPENLANDER, J. C., "Variables Influencing Spot-Speed Characteristics." *Highway Research Board Special Report* 89, 1966, pp. 1-39.

Descriptors: vehicular speeds; driver and roadway variables.

This paper is confined to those articles on vehicular-speed characteristics that appear to be a definite contribution to the disciplines of highway and traffic engineering. In summarizing driver variables, trip distance has the most significant influence on spot-speed characteristics, whereas passengers in a car and the sex of the driver are of little importance. Vehicular spot speeds are most significantly influenced by functional classification, curvature, gradient, etc.

- 5.17 WILSON, ROGER E., "Unique Traffic Count Provides Maximum Info at Low Cost." *Traffic Engineering*, Vol. 35, No. 10, July, 1965, pp. 18-20 and 52-54.

Descriptors: traffic counts; low cost.

It is recognized that the data obtained in this study encompass a narrow range because of the limited nature of the study. The procedures, however, show promise as a method of obtaining low cost traffic information in residential areas.

D. STATISTICAL PROCEDURES

- 5.18 HEATHINGTON, KENNETH W., AND JONES, ANDREW D., "An Analysis of Peak Period Freeway Volume Characteristics," *Traffic Engineering*, Vol. 36, No. 8, May, 1966, pp. 34-37.

Descriptors: freeway volume; 5-minute counts.

The purpose of this study of 5-minute count volumes was to determine if a volume of short duration could be expanded to give a volume for a longer time interval with reasonable accuracy.

- 5.19 STANBURY, N. W., "Speed Measuring Radar," *Industrial Electronics*, Vol. 2, No. 12, Dec., 1964, pp. 549-52.

Descriptor: radar speed.

System using Doppler radar for measuring speed of autos; block diagram of device called PETA (portable electronic traffic analyzer) by Marconi Co., Ltd.; extension of speed range by increasing angle between beam and target is shown; equipment for measuring velocity and retardation of projectiles is also discussed.

- 5.20 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.

Descriptors: simulation; traffic flow; interchanges; loop detectors.

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.

- 5.21 TAYLOR, D. G. AND SNOW, F. A. "Analysis of Dynamic Data." *AEI Engineering*, October, 1963, pp. 60-65.

Descriptors: mathematical models; digital computation.

Methods are outlined for digital computation of mathematical models describing processes to be controlled.

- 5.22 "Traffic Surveillance Trail at Vauxhall Cross," SURVEYOR, Vol. 71, No. 3785, p. 16, Dec. 19, 1964. Highway Research Abstract, Vol. 35, No. 4, April, 1965, p. 8.

Descriptors: surveillance.

The Ministry of Transport (MOT) is running a trial at Decca Radar Ltc. traffic surveillance equipment in the Vauxhall Cross area. The system, uses the Decca "Color-matic" traffic map which shows traffic movement over a large area at a glance. Vehicle detectors operate green arrows and amber dots and red arrows to show what vehicles are doing at certain points. These colored lights pertain to speed of vehicles.

- 5.23 "Traffic Volumes Now Machine Plotted," Traffic Engineering, Vol. 35, No. 4, January, 1965, pp. 54 and 58.

Descriptors: flow maps; machine plots.

Traffic volumes and flow maps are being machine-plotted directly from the traffic assignment output tapes. The output of this program, contained in card form, becomes the input to a program which uses a computer plotter to produce the flow map.

- 5.24 WILBUR, DONALD E. "Automation in Map Data Collection for Engineering Computer Programs." Presented as a paper to the 45th Annual Meeting of the Highway Research Board, January 17-21, 1966. Highway Research Record 142, 1966, pp. 39-46

Descriptors: data processing; map data.

This paper deals with the methods and procedures currently being utilized by the Pennsylvania Department of Highways in the collection of map data for engineering computer programs. It discusses: (a) the gathering of map and textual data and the recording of this information on IBM cards with EAI electronic-coordinator and recording system attached to an IBM 526 summary punch; (b) the processing of this information on the IBM 7040 computer; and (c) the plotting of the resultant data by the EAI 3500 Dataplotter.

- 5.25 ZUPANICK, J. E. "Vehicle Classification Sensors for Automatic Traffic Control," U. S. Bur. Public Roads, Conference on Traffic Surveillance, Simulation, and Control Proceedings, Sept. 14-15, 1964, pp. 32-42.

Descriptors: vehicle classification; sensors-design, use.

Sensing function in automatic traffic control system is defined and analyzed and application of electro-optical techniques to achieve better highway traffic control is suggested; design and use of optic-fiber-array comb filter and correlation frequency analyzer for classifying vehicle.

F. TELEVISION

- 5.26 EDWARDS, FRED, "Television Era in Traffic Control," Texas Highways, Vol. 11, No. 7, pp. 14-16, July 1964, Highway Research Abstracts, Vol. 34, No. 11, Nov., 1964, p. 26.

Descriptors: television; traffic control; tunnel.

This article describes a closed circuit television system in the Baytown-LaPorte (Texas) tunnel. The operator observes traffic conditions and regulates traffic signals in the tunnel.

- 5.27 "Seattle Freeway Traffic Handled by T.V. Cameras," Western Construction, Vol. 38, No. 9, August 1963, p. 72. Highway Research Abstracts, Vol. 34, No. 3, March, 1964, pp. 3-4.

Descriptors: control; television; reversible lanes.

This article discusses a traffic control system run by one operator using 11 cameras. The Seattle Freeway, normally an 8-lane highway, will be supplemented with four reversible lanes for use in the rush hours. The control system will automatically meter the traffic and operate all control devices along the reversible sections. The T.V. cameras will enable the operator to observe conditions prior to operating the control system. These controls will activate barriers and swing gates to direct traffic and will also meter the necessary traffic signals to provide a continuous smooth flow of traffic.

- 5.28 KELLER, OLIVER, "Centralized Traffic Control by Signals & Television," Traffic Engineering, Vol. 36, No. 11, August, 1966, pp. 21-25.

Descriptors: control; television, signals.

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.

SECTION 6

THEORETICAL STUDIES, MATHEMATICAL MODELS,
AND SIMULATIONA. STATISTICAL AND EMPIRICAL THEORIES

- 6.01 CLARK, COLIN, AND PETERS, G. H. "The Intervening Opportunities' Method of Traffic Analysis." Traffic Quarterly, Vol. XIX, No. 1, pp. 101-119.

Descriptors: traffic analysis; models.

This paper deals with the mathematical analysis of traffic flows.

- 6.02 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.

Descriptor: traffic control system.

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. The control problem is not treated in great detail.

- 6.03 DRAKE, JOSEPH, SCHOFER, JOSEPH, AND MAY, ADOLF D. "A Statistical Analysis of Speed-Density Hypotheses." Highway Research Record No. 154, 1966, pp. 53-87.

Descriptors: traffic flow parameters; statistical analysis.

During recent years a number of hypotheses have been proposed to describe the relationships between basic stream flow characteristics. This paper deals with an investigation conducted to compare these theories using a common set of data collected on the Eisenhower Expressway in Chicago. The ability of various functions to predict flow parameters over the range of operating conditions was evaluated with statistical techniques; sound judgment was applied where statistics were impossible.

- 6.04 DREW, D. R. "Gap Acceptance Characteristics For Ramp-Freeway Surveillance and Control." TTI Research Report 24-12, July, 1965, 43 pp.

Descriptors: gap acceptance; merging delay; critical gaps; ramps.

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. The critical gap for stopped 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 lane control.

A distribution of critical gaps was found and fitted to a gamma distribution. Merging delay values calculated using the distribution were shown to be higher than those calculated assuming that all drivers have the same critical gap. The calculated values were also compared to observed merging delays.

- 6.05 DREW, D. R. "Stochastic Considerations in Freeway Operations and Control." TTI Research Report 24-5, June, 1965, 54 pp.

Descriptors: stochastic approach; Erland distributions; moving queues.

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.

- 6.06 DREW, D. R. "Theoretical Approaches to the Study and Control of Freeway Congestion." TTI Research Project 24-1, January, 1964 27 pp.

Descriptors: congestion; deterministic models - macroscopic, microscopic.

This article discusses the possibility of reducing freeway congestion in the form of controls on the freeway and the metering of inputs on the freeway. The problems of freeway operation and control are described by deterministic mathematical models. By showing a generalization and comparison of macroscopic and microscopic models of traffic flow the applicability of these deterministic models to freeway traffic is readily seen. Such macroscopic parameters as capacity and the optimum speed provide good indices of congestion and bases for control.

The need for a more sensitive indicator of congestion than density led to the formulation of the moving queues model. The expected number of vehicles per moving queue provides a quantitative index of congestion. The congestion index developed offers more than a subjective means of evaluating freeway performance.

- 6.07 GERLOUGH, D. L. AND CAPELLE, DONALD C.
"An Introduction to Traffic Flow Theory."
Highway Research Board Special Report 79,
1964, 145 pp.

Descriptors: traffic flow-simulation; fluid flow; queuing theory; control; bibliography.

This paper discusses traffic flow from several angles. Chapter 1 discusses traffic flow theories in terms of fluid or hydrodynamic flows. Chapter 3 discusses queuing theory approaches. Chapter 4 discusses simulation of traffic flow. Chapter 5 deals with experiments with drivers, platoon studies, models, flow control, and intersection control. Appendix A is a bibliography on the theory of traffic flow and related subjects.

- 6.08 GREENBERG, TRININ AND CRAWLEY, KENNETH W.,
"Holland Tunnel Study Aids Efficient Increase of Tube's Use," Traffic Engineering,
Vol. 35, No. 6, March, 1965, pp. 29-22.

Descriptors: headways; velocities; density; travel time.

Samples of vehicle headway times and velocities have been collected simultaneously at up to six points in a line of the Holland Tunnel. Spatial densities and travel times have been calculated for the inter-point segments. Analyses have been made of point and segment vehicular characteristics with particular attention given to those which appear to act as prior indicators, either in space or time, of congestion. Finally, these findings will be discussed in terms of their utility in altering and improving the existing tunnel traffic flow control system.

- 6.09 OPPENLANDER, J. C. "Theory of Traffic Flow-Statistical Models." Presented to the 50th Annual Purdue Road School, March 23-26, 1965. Printed in the Engineering Extension Series, No. 116, pp. 121-132.

Descriptors: traffic flow; statistical models.

The purposes of this paper are to provide an introduction to the theory of traffic flow and to illustrate several statistical models that have been developed to describe various traffic stream characteristics.

- 6.10 WHEELER, ROBERT J., AND TORY, EIMER M.
"The Use of the Flux Plot in Traffic Control," Traffic Quarterly, Vol. XIX, No. 3, July, 1965, pp. 369-383.

Descriptors: traffic control; kinematic waves.

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.

- 6.11 WORTMAN, ROBERT H., "A Multivariate Analysis of Vehicular Speeds on Four-Lane Rural Highways," Highway Research Record No. 72, 1965, pp. 1-18.

Descriptor: Mathematical model - spot speed.

This paper discusses the study of vehicular speeds on 4-lane highways in rural areas. The purpose was to evaluate the variables that represent the driver, the vehicle, the roadway, traffic conditions and environmental characteristics. Mathematical models were devised to predict mean spot-speeds. These models produced equations which were developed by the use of multiple correlation and linear regression analysis. Mean spot-speed, as a result of the study, could be predicted with a reasonable degree of statistical accuracy and that this estimation could be based on a limited number of variables or common factors.

B. MATHEMATICAL MODELS

- 6.12 BECKMANN, MARTIN J. "On the Theory of Traffic Flow in Networks." Traffic Quarterly, Vol. XXI, No. 1, January, 1967, pp. 109-116.

Descriptors: traffic flow; networks.

This article discusses problems in developing a theory of transportation network which might predict properties of traffic flow in various segments of the network.

- 6.13 CAPELLE, DONALD G., "An Investigation of Acceleration Noise as a Measure of Freeway Level of Service," A Dissertation submitted to the Graduate College of the Texas A&M University, May, 1966, 124 pp.

Descriptors: acceleration noise; traffic flow; fuel consumption.

The primary objective of this study is to investigate the acceleration noise of vehicles on a freeway and relate this parameter to well-established quantitative measures of traffic flow. This will involve correlating acceleration noise with average measures of volume, density and speed.

Using acceleration noise as a qualitative measure of freeway traffic flow, an attempt will be made to establish a quantitative description of the four zones of freeway flow described in the Highway Capacity Manual. A second objective is to study the relationship of freeway traffic flow to fuel consumption.

- 6.14 DREW, DONALD R., "Deterministic Aspects of Freeway Operations and Control." TTI Research Report 24-4, June, 1965, 53 pp.

Descriptors: speed; density; volume; compressible fluid model; car-following model; time lapse photography; contour maps.

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 the 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.
- 6.15 DREW, DONALD R., "The Energy-Momentum Concept of Traffic Flow," *Traffic Engineering*, Vol. 36, No. 9, June, 1966, pp. 52-54.
- Descriptor: traffic flow - energy-momentum concept.
- This is the eighth of nine monthly articles on the classification and application of traffic models.
- 6.16 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, pp. 1-88.
- Descriptors: acceleration noise; control; grades; level of service; traffic flow.
- 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 procedures 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.
- 6.17 DREW, DONALD R., DUDEK, CONRAD L., AND KEESE, CHARLES J. "Freeway Level of Service as Described by an Energy-Acceleration Noise Model." *Highway Research Record No. 162*, 1966, pp. 30-85.
- Descriptors: acceleration noise; energy model; momentum.
- The standard deviation of acceleration of a vehicle is called acceleration noise. The acceleration noise obtained in the absence of traffic is ascribed to the geometrics of the facility and is called natural noise. The acceleration noise for the vehicle obtained during periods of normal freeway operation, the amount of acceleration noise in excess of the natural noise of the facility is assumed to be due to the existing traffic interaction. This acceleration noise parameter is fitted to a fluid dynamics "energy Model."
- A single stream of traffic offers a very strong analogy to the flow of a compressible fluid in a constant area duct, suggesting that the conditions of continuity of momentum and energy should be fulfilled at the surface of a traffic shock wave, just as the equations of dynamic compatibility must be fulfilled in fluid dynamics. Because in a classical system, the conservation of momentum equation serves to establish the form for momentum, the quality "density times speed" is defined here as the "momentum" of the traffic stream. Since "momentum" is equivalent to traffic flow, such flow-oriented parameters as capacity, critical speed, and critical density are, in effect, based on maximizing this momentum.
- 6.18 DREW, DONALD R., "The Macroscopic Approach to Traffic Flow," *Traffic Engineering*, Vol. 36, No. 7, April, 1966, pp. 70-71.
- Descriptor: traffic flow model-macroscopic.
- This is a sixth in a series of nine Traffic Engineering articles on traffic models.
- 6.19 DREW, DONALD R., "Traffic Models - Summary," *Traffic Engineering*, Vol. 36, No. 10, July, 1966, pp. 45-57.
- Descriptor: traffic models.
- This paper is about the classification and application of traffic models.
- 6.20 EDIE, LESLIE C., "Analytical Methods in Transportation; Operations Research in Tunnel Traffic Control," *Journal of the Engineering Mechanics Division, ASCE* Vol. 89, No. EM6 Proc. Paper 3716, pp. 15-28, Dec., 1963. *Highway Research Abstracts*, Vol. 34, No. 3, March, 1964, p. 12.
- Descriptors: control in tunnels; operations research.
- This report discusses the traffic in the Hudson River Tunnels; how back-ups have been reduced as well as delays and heavy concentration inside the tunnel; elimination of shock waves emanating from bottlenecks, increase of speed; reduction of breakdowns and accidents; and reduction of fumes.
- 6.21 FELDBAUM, A. A. "Application of Theory of Statistical Solutions to Open and Closed-Loop Automatic Control Systems." *Engineering Cybernetics* (English translation of *Tekhnicheskaya Kibernetika*) No. 1, Jan.-Feb. 1963, pp. 1-12.

Descriptors: dual control theory; reducible irreducible systems; closed and open - systems.

Open and closed-loop systems are compared; concepts of reducible systems, i.e., such closed-loop systems for which equivalent open-loop systems exist, and of irreducible systems are introduced; systems with noninertial controlled object are extended to systems with inertial controlled object; investigation of closed-loop systems is based on formulas derived from theory of dual control.

- 6.22 GERLOUGH, D. L., AND CAPELLE, DONALD C. "An Introduction to Traffic Flow Theory." Highway Research Board Special Report 79, 1964, 145 pp.

Descriptors: traffic flow; simulation; fluid flow - queueing theory; control; bibliography.

This paper discusses traffic flow from several angles. Chapter 1 discusses traffic flow theories in terms of fluid or hydrodynamic flows. Chapter 3 discusses queueing theory approaches. Chapter 4 discusses simulation of traffic flow. Chapter 5 deals with experiments with drivers, platoon studies, models flow control, and intersection control. Appendix A is a bibliography on the theory of traffic flow and related subjects.

- 6.23 GRACE, MURIEL J., AND POTTS, RENFREY B., "A Theory of Diffusion of Traffic Platoons," Operations Research, Vol. 12, No. 2, pp. 255-275, March-April, 1964. Highway Research Abstracts, Vol. 34, No. 7, July, 1964, pp. 15-16.

Descriptor: traffic platoons.

A theoretical investigation is made of the diffusion of a traffic platoon as it moves down the road.

- 6.24 MAY, A.D. AND KELLER, HARMUT E. M. "Non-Integer Car-Following Models." Highway Research Record No. 199, 1967, pp. 19-32.

Descriptor: car-following models.

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.

- 6.25 OLIVER, ROBERT M., "Travel Times Through Shock Waves," Operational Research Quarterly, Vol. 15, No. 2, pp. 139-144, June, 1964. Highway Research Abstracts, Vol. 34, No. 11, November, 1964, pp. 18-19.

Descriptors: shock waves; travel times.

In this paper on traffic streams the author formulates the well-known principle of conservation of matter with an integral equation expressing travel times in the stream. A traffic situation is investigated where time-dependent flow rates into a bottleneck temporarily exceed its capacity. Expressions are found for queue sizes, the location and velocity of shock waves, and delays to vehicles in the stream.

- 6.26 PIPES, L.A. "Wave Theories of Traffic Flow," Franklin Institute Journal, June-July, Vol. 280, No. 1, pp. 23-41.

Descriptor: wave theories.

Use of "hydrodynamic" model and car-following and control-system models to explain empirical observations that form of "wave phenomenon" occurs when a line of vehicles on a crowded highway is stopped or started by signal.

- 6.27 ROTHERY, R., SILVER, R., HERMAN, R., AND TORNER C. "Analysis of Experiments on Single-Lane Bus Flow," Operations Research, Vol. 12, No. 6, Nov.-Dec., 1964, pp. 913-33.

Descriptors: bus-flow; models.

Using pairs of buses theoretical 'car-following' models of single lane traffic flow are examined for this type of heavy vehicle and found to provide good representation of detailed manner in which one bus follows another; flow characteristics of buses were also determined by using platoons of up to ten buses; approaches showed respectively that single lane of buses form stable stream of traffic and have optional flow of about 1450 buses/hr. at speed of 33 mph. for expressway type facility.

- 6.28 UNDERWOOD, R. T. "Traffic Flow and Bunching" Australian Road Research Journal, Vol. 1, No. 6, pp. 8-25, June 1963, Highway Research Abstracts, Vol. 34, No. 1, January, 1964, pp. 5-6.

Descriptors: flow zones; mathematical models; bunching, traffic flow.

In this paper the general flow diagram that postulates that there are three distinct flow zones has been further discussed. The application of various mathematical models of flow to each of these zones is considered. The bunching of traffic is discussed, and the results of some limited studies are set out. This paper is a sketchy coverage of traffic flow and bunching, and its main purpose is to record some thoughts that might be expanded at length by others.

- 6.29 WEINER, MELVIN M. "Directional Traffic Flow." Traffic Quarterly, Vol. XX, No. 4, October, 1966, pp. 589-608.

Descriptors: traffic flow; road networks; topological concepts.

In order to apply the favorable one-way street experience of United States to a larger number of road networks, a scientific method is needed for determining the feasibility of unidirectional traffic flow in a road network of arbitrary geometry.

The accessibility of one-way streets in road networks of arbitrary geometry is determined by utilizing topological concepts. Trees and independent cycles are utilized to orient the roads of a unidirectional road network so that it is strongly connected. It is shown that any road network, excluding isthmuses and pendant edges, can be unidirectional and still be strongly connected. Evaluation

of certain geometric parameters in the topological graph of an arbitrary road network is suggested for determining the potential feasibility of unidirectional traffic flow. The one-way street experience of the U. S. is summarized. Some of the differences between topological graphs and directional flow graphs are reviewed.

- 6.30 WEISS, G. H., Operations Research, Vol.12, No. 6, Nov.-Dec., 1964, pp. 832-57.

Descriptors: merging; queues-steady state; waiting times; critical input.

Study of several aspects of theory of car queues for situation in which there is traffic on main highway and queue of cars on side road waiting to merge; expressions for generating function of steady - state and waiting - time distribution are derived; critical input to side road is determined such that for all large inputs queue is transient; effect of move up time on queue is considered in particular. 20 refs.

- 6.31 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.

Descriptors: mathematical formulae; traffic control.

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.

- 6.32 WOJCIK, C. K., AND PIPES, L. A. "A Study in Wave Theories of Traffic Flow." Bulletin of the Operations Research of America, Vol. 14, Supp. 1, pp. B98-B99, Spring, 1966, Highway Research Abstracts, Vol. 36, No. 11, Nov., 1966, p. 14.

Descriptors: wave phenomenon; mathematical models.

This study presents mathematical models explaining the "wave phenomenon" as observed in actual traffic.

C. TRAFFIC SIMULATION

- 6.33 BRAUNSTEIN, MYRON L., AND LAUGHERY, KENNETH R. "Computer Simulation of the Automobile Driver: A Model of the Car Follower," Highway Research Record No. 55, 1964, pp. 21-28.

Descriptors: computer simulation; driver behavior - car following, interstate.

This study is directed toward development of a digital computer program of the information on processing type, which simulates the behavior of the individual driver in interstate highway car-following. Objective measurements and verbal reports were collected. A preliminary information processing model was prepared in flow chart form. Quantitative detail was added to the model using data extracted from existing literature and from several experiments conducted also.

- 6.34 DAWSON, ROBERT F., AND MICHAEL, HAROLD L. "Freeway On-Ramp Capacity Analysis by Monte Carlo Simulation and Queueing Theory," Highway Research Record No. 118, 1966, pp. 1-20.

Descriptors: on-ramp design, capacity; Monte Carlo simulation; queueing theory.

This report is concerned with the analysis of the capacities of three different freeway on-ramp designs. Included were the development of criteria for defining both possible and practical capacities, development of a deterministic queueing model for predicting possible capacity, development of a Monte Carlo Simulation model for the study of ramp flow under varying traffic conditions, evaluation of vehicle delays and queue lengths incurred by on-ramp vehicles for various combinations of ramp and shoulder lane traffic volumes, and evaluation of possible and practical on-ramp capacities for the three different ramp designs.

- 6.35 DREW, DONALD R., MESESOLE, THOMAS C., AND BUHR, JOHANN H. "Digital Simulation of Freeway Merging Operation," TTI Research Report 430-6, 53 pp.

Descriptors: simulation methodology; merging.

This publication can be considered as consisting of two parts. The accent of the first part is on the simulation of vehicular traffic in general. Techniques, methods, and procedures of simulation commonly used are treated in detail. The second part of the paper describes a computer program developed for the simulation of a ramp-freeway junction. Some of the output of the program are presented as evidence of its capability of representing the merging process realistically.

- 6.36 FOX, PHYLLIS, AND LEHMAN, F. G. "A Digital Simulation of Car Following and Overtaking," Highway Research Record No. 199, 1967, pp. 33-41.

Descriptors: simulation - car following, overtaking; safe driving situation.

A model representing the single-lane no-passing driving situation has been formulated and run on a digital computer. The model allows for human factors and variation between drivers. The study has been directed to the accident prevention problem with the aim of determining the critical parameters of the driving situation, and of ascertaining the ranges of values of these parameters which define a safe or stable driving situation.

- 6.37 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.

Descriptors: simulation; diamond interchange - design.

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.

- 6.38 GERLOUGH, D. L., AND CAPELLE, DONALD C., "An Introduction to Traffic Flow Theory." Highway Research Board Special Report 79, 1964, 145 pp.

Descriptors: traffic flow; simulation; fluid flow; queueing theory; control; bibliography.

This paper discusses traffic flow from several angles. Chapter 1 discusses traffic flow theories in terms of fluid or hydrodynamic flows. Chapter 3 discusses queueing theory approaches. Chapter 4 discusses simulation of traffic flow. Chapter 5 deals with experiments with drivers, platoon studies, models, flow control, and intersection control. Appendix A is a bibliography on the theory of traffic flow and related subjects.

- 6.39 HULBERT, S. AND WOJCIK, C. "Research Activities at the UCLA Driving Simulation Laboratory." Highway Research News 17, Feb. 1965. pp. 111-114.

Descriptors: simulation; driver behavior; wrong-way driving.

This paper discusses an automated data recording and processing system developed at UCLA - Institute of Transportation and Traffic Engineering. Two studies of driver behavior are presented. One deals with driver failure due to physical weaknesses. The other is a wrong-way ramp study.

- 6.40 KIDD, EDWIN, AND LAUGHERY, KENNETH R. "A Computer Model of Driving Behavior: the Highway Intersection Situation," Highway Research Record No. 148, 1966, pp. 88-99.

Descriptors: driver behavior - simulation; highway intersection.

This paper explains that a digital computer model of the perceptual, decision-making, and response processes of the driver has been formulated for the highway intersection situation. The model presents a simulation of human behavior in a dynamic control task. It is concluded that the model is reasonable and realistic and forms a basis for further study of human driving behavior.

- 6.41 MAST, TRUMAN M., JONES, HOWARD V., AND HEIMSTRA, NORMAN W. "Effects of Fatigue on Performance in a Driving Device." Highway Research Record No. 122, 1966, p. 93.

Descriptors: driving simulator; fatigue.

The present investigation was designed to determine the effects of fatigue on several performance tasks required in the operation of a driving simulator. The investigation tends to indicate that there may be considerable differences between tasks in a driver's demonstrated sensitivity to fatigue. Some tasks required of the operator showed a performance decrement, others showed no decrement, whereas a definite improvement in performance was shown on other tasks. The results also

suggest that subjects adjust their effort to the expected duration of the task.

- 6.42 MORTIMER, RUDOLF G. "The Effect of Glare in Simulated Night Driving." Highway Research Record No. 70, 1965, pp. 57-62.

Descriptors: night vision; simulation.

Two experiments were carried out in the laboratory in which illumination and glare conditions in night driving were simulated. Steering accuracy was measured as the dependent variable. The interactions between roadway illumination, glare illumination, glare duration, and glare frequency were investigated.

- 6.43 PASSAU, P. H. "Delays Incurred by Vehicles Stopped at Traffic Lights." International Road Safety and Traffic Review, Vol. 11, No. 3, pp. 13-14, Summer 1963, Highway Research Abstracts, Vol. 34, No. 1, Jan. 1964, pp. 13-14.

Descriptors: delays; signalized intersections; phasing; Markovian process.

This paper examines the statistical characteristics of vehicles stopped by traffic lights. It is assumed that the interarrival times between vehicles are exponentially distributed, and that the departing time of the stopped vehicles depends linearly on their rank in the queue. Formulae are given for the average delay incurred by the vehicles in relation to the length of the red period.

The results can be extended to traffic lights with a fixed phase. Therefore, the optimal periods can be computed.

Finally it is evident that the adaptation of traffic light phases in accordance with actual traffic conditions will reduce the delay to vehicles. The Markovian process generated by such a control has been described, and the decrease in the delay has been computed.

- 6.44 READING, ROGERS W. AND HOFSTETTER, HENRY W. "Extra Horopteral Stereopsis in Vehicle Operator Orientation." Highway Research News 17, 1965, pp. 84-90.

Descriptors: driver behavior; simulation.

Experimental facilities are described for measuring roadway tracking performance under conditions of continuous mechanical interference in the tracking mechanism during which extra horopteral Stereovisual clues are provided. Data from two trained subjects are presented in terms of a specially derived performance index formula.

- 6.45 SCHLESINGER, Lawrence, and SAFRENI, MIRIAM. "Perceptual Analysis of the Driving Task," Highway Research Record No. 84, 1965, pp. 54-61.

Descriptor: driving task model.

This paper attempts to develop a unified and comprehensive model of the driving task which has practical and psychological validity. The model specified the

critical tasks of driving, the critical skills to perform these tasks, and some objective measures of these skills. The major tasks, in the model, for the driver are the perceptual organization from moment to moment of a field of safe travel, a minimum stopping zone, and a comparison of these two fields.

- 6.46 SHUMATE, ROBERT P. "A Simulation System for the Study of Traffic Flow Behavior," Highway Research Record No. 72, 1965, pp. 19-39.

Descriptors: simulation; traffic flow;
2-lane highway.

This paper discusses a simulation model which was developed to permit variable specification of roadway and traffic parameters to the extent that any physical configuration of a 2-lane highway with intersections can be presented. The movement of the model through time is carried out in simulated 1-sec intervals during which each vehicle is updated. A "Source" language also was designed for use in specifying simulation problems. Finally, validation of the model has been undertaken by comparing simulated output with data gathered from measurement of actual highway segments.

- 6.47 SILVER, CARL A. "Performance Criteria - Direct or Indirect." Highway Research Record No. 55, 1964, pp. 54-63.

Descriptors: driver fatigue; simulation.

This paper considers the theoretical nature of fatigue and develops a method to measure fatigue.

- 6.48 TODOSIEV, E. P., "Applications of the Automobile Simulator," Highway Research Record No. 25, 1964, pp. 102-105.

Descriptors: automobile simulator; car following - velocity thresholds.

This paper discusses an experiment performed on a driver in an automobile simulator to determine the driver's average velocity threshold when he is following a lead vehicle under dense traffic conditions. Application of Stevens psycho-physical law to the velocity threshold equations that interrelate the headway, threshold velocity, and presentation time. The variation of threshold velocity with headway was also determined.

- 6.49 WOJCIK, CHARLES K., AND HULBERT, SLADE. "Part - Task Simulators at U.C.L.A." Presented as a paper to the 45th Annual Meeting of the Highway Research Board, January 17-21, 1966.

Descriptors: driving simulators; signing.

In this article two part-task simulators are described. One is a sign tested developed to help highway and traffic engineers evaluate the effectiveness of certain highway signing. The other device is a proposed closed-circuit television display system for the existing fixed-based driving simulator. The purpose of this equipment is to determine the passing and car-following habits of various drivers.

SECTION 7

SIGNING, MARKING, AND SIGNALIZATION

- 7.01 ALLEN, T. M., DYER, F. N., SMITH, G. M., AND JANSON, M. H. "Luminance Requirements for Illuminated Signs." Highway Research Record No. 179 1967, pp. 16-37.

Descriptors: sign-legibility; brightness.

Various combinations of black and white letters and backgrounds were night-tested in the field, using an internally illuminated sign, to collect data on the relationship between sign luminance and legibility over a range of lighting conditions.

- 7.02 ANDERSON, J. W. AND CARLSON, G. C. "Vehicle Spray Pattern Study." Highway Research Record No. 179, 1967, pp.38-52.

Descriptors: milepost markers - vertical and lateral placement; spray patterns; interstate.

The purpose of this study was to investigate the pattern of spray from passing vehicles with respect to determining the optimum lateral and vertical placement of milepost markers for an interstate-type highway with wide, paved shoulders.

- 7.03 AUSTIN, J. E. "Fog-Proof System." American City, Vol. 79, No. 3, March 1964, pp. 113-114

Descriptors: marking; lighting; roadway delineation.

Roadway delineation marker-light system was installed on 3,500 ft. section of Oakland, Calif., Boulevard; glare-controlled mercury vapor luminaires supplement marker lights at intersections and other points of potential traffic conflicts.

- 7.04 "Background to Worboys." Surveyor, Vol. 123, No. 3746, March 21, 1964, pp. 41-42, 51-54.

Descriptors: signing-recommendations; basic requirements.

Recommendations of committee on traffic signs for all-purpose roads in Great Britain; basic requirements of traffic signs, size of letters, overhead signs, color of signs, sign illuminations, layout, sitting of advance direction signs, general small signs, and characteristics of protocol signs are described.

- 7.05 BEATON, JOHN L., AND ROONEY, HERBERT A. "Raised Reflective Markers for Highway Lane Lines." Highway Research Record No. 105. 1966, pp. 1-7.

Descriptors: lane lines; raised reflective markers.

This paper discussed California's practice of using a broken white strip to delineate traffic lines. The painted portion is beaded for night visibility. It has long been observed by motorists that during periods of inclement weather and moderate-to-heavy rainfall at night that water tends to accumulate on the pavement to a depth sufficient to cover and obscure the beaded painted centerline traffic stripe. Under such conditions, light from a motor vehicle is not reflected back to the

driver and he is unable to see the painted stripe. In this situation the driver often finds it difficult to remain in his traffic lane.

- 7.06 BEVINS, KARL A. "'They Should Help 'Us' Realize More Efficiency from 'Our' Street System." Traffic Quarterly, Vol. XIX, No. 1, January 1965, pp. 133-137.

Descriptors: signs; signals; markings; design; motorist.

This article discusses signs, signals, and markings designed to aid the motorist in getting the best possible service from the system.

- 7.07 "Blue Guard Rail Identifies Service Area," Rural and Urban Roads, Vol. 2, No. 4, p.53, April, 1964, Highway Research Abstracts, Vol. 34, No. 6, June, 1964, pp. 1-2.

Descriptors: guard rails; service area.

This report discusses the use of blue guard rails to identify service areas and tells how they are painted and with what.

- 7.08 BRECKENRIDGE, F. C. "United States Standard for the Colors of Signal Lights." National Bureau of Standards, U.S. Dept. of Commerce, Handbook 95, August 21, 1964, 30 pp. Highway Research Abstracts, Vol. 35, No. 4, April, 1965, p. 8.

Descriptor: signal light colors.

The standard provides basic chromaticity definitions for those considered safe for use as representing the named colors. These are the basis for the selection of the national standard filters and for the tolerances for duplicating them. The procurement requirements are based primarily on sets of these filters in combination with prescribed sources, although provision is also made for procurement under the basic chromaticity definitions in cases in which the form is impracticable. Guidance in selecting signal colors for new uses is provided as well as methods for special laboratory tests and a technical interpretation of the practical tests prescribed.

- 7.09 BROOKS, H. M. "Electronic Computer Analysis of Overhead Sign Structures." American Association of State Highway Officials - Committee on Electronics - Regional Conference on Improved Highway Engineering Productivity, Chicago, Ill., April 19-20, 1963, p. VIII 36-42.

Descriptor: overhead sign structures - computer analysis.

Program design at Bridge Division of Tennessee Highway Dept. written for IBM 1620; program is designed in aluminum using alloy 6062-T6 for major structural members and alloy 6063-T6 for bracing members and was written in Fortram language and occupies 55,000 digits of core storage.

- 7.10 BUSHNELL, KEITH, AND RICHARD, CHARLES. "The Development of Blankout Signals (for Freeway Traffic Control)," Traffic Engineering, Vol. 34, No. 5, February, 1964. pp. 19-24.

Descriptors: freeway signals; ramp control; lane control; speed control.

Blankout legend signals have been used successfully for several years as pedestrian "Walk/Don't Walk" signals. This discussion covers the development and use of "blankout" signals lane control, speed control, and ramp control; and the problems encountered in developing the "blankout" signal for these uses.

- 7.11 "California Tries to Stop Wrong-Way Freeway Entries," Western Construction News, Vol. 40, No. 7, p. 92, July 1965. Highway Research Abstracts, Vol. 36, No. 3, March, 1966, p. 8.

Descriptor: signing - wrong-way entries.

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

- 7.12 DALE, J. M. "Nighttime Use of Highway Pavement Delineation Materials." (Abridgement) Highway Research Record No. 179, 1967, p. 74, National Cooperative Highway Research Program Report No. 45, 1967.

Descriptor: delineations - methods, materials.

In this study, ways of improving delineation of roadways under wet and dry conditions by either improving techniques utilizing existing materials or developing new materials and techniques were investigated.

- 7.13 DART, OLIN K., JR. "A Study of Roadside Delineator Effectiveness on an Interstate Highway," Highway Research Record No. 105, 1966, pp. 21-48.

Descriptors: delineators; speeds; vehicle placement.

This research was initiated to determine if post-mounted reflective delineators placed along Interstate highways were effective and valuable enough as a traffic control device to warrant their installation and maintenance. Analysis showed mean speeds to be some 2 mph lower under delineated conditions than under nondelineated conditions, but this difference was not considered to be significant from a practical standpoint; there was no significant effect of delineation on vehicle placement.

- 7.14 DEAKIN, OLIVER A. "Planting for Screening Headlight Glare and Traffic Guidance." Highway Research Record No. 53, 1964, pp. 17-25.

Descriptors: roadside planting; safety; driver guidance; headlight glare.

This is a supplemental report on "Planting for Screening Headlight Glare and Traffic Guidance" to record and show what progress has been made in the use of various species of plant materials for special problems. This record of information as of 1963, is to supplement information already published by the Highway Research Board (1, 2, 3). The Committee is interested in the functional use of plant materials

along roadsides for the purpose of making the highways safer to drive, more attractive and pleasant to travel, and less costly to maintain.

- 7.15 DREW, DONALD RICHARD, "An Analysis of Peak Traffic Demand at Signalized Urban Intersections," A thesis submitted to the Graduate School of the A&M University, August, 1961, 97 pp.

Descriptors: signalized intersections; capacity; design.

This report represents an attempt to analyze the arrival of vehicular traffic during the A. M. and P. M. peak hours at signalized intersections located in urban areas. Data on vehicle arrivals were obtained from 60 intersection approaches located in eight major Texas cities. Through a multiple regression analysis based on the sample of 60 intersection approaches, the magnitude of the peak period was expressed in terms of city population, intersection location and the number of vehicles arriving at the intersection on a given approach within the peak hour. The distribution of vehicle arrivals during the peak hour and peak period were analyzed. Finally, some of the aspects of the capacity-design analysis of an intersection are considered, and two new design procedures are suggested.

- 7.16 DREW, D. R. "Design and Signalization of High-Type Facilities," Reprinted from Traffic Engineering, July, 1963.

Descriptors: intersections; interchange; designs; signals; planning; peak period traffic demand.

This paper is a summary of research analyzing traffic at urban signalized intersections and interchanges during the A. M. and P. M. peak hours. A procedure for planning, designing, signalizing and analyzing signalized facilities has been based on this study.

The findings provide both a basis for new design procedure and a means for perfecting existing procedures.

- 7.17 "Directional Signing on Metropolitan Freeways: A Progress Report, 1963," Automobile Club of Southern California, July 3, 1963, Highway Research Abstracts, Vol. 34, No. 6, June, 1964, pp. 10-11.

Descriptor: directional signing.

This report discusses certain signing problems on freeways and the efforts to conquer them.

- 7.18 "Experimental Traffic Sign," Rural and Urban Roads, Nov. 1963, p. 52, Highway Research Abstracts, Vol. 34, No. 5, April, 1964, p. 11.

Descriptor: signing - wrong way.

This report discusses a sign that warns motorists when they are going the wrong way on a one-way street.

- 7.19 FAIRFAX, BARRY U., "Methods of Signalizing Left-Turn Movements at Channelized Intersections." *Traffic Engineering*, Vol. 37, No. 8, May, 1967, pp. 48-54.

Descriptors: signalization; left-turns; channelized intersections.

The purpose of this study was to determine what type of signal indication, shown to the left-turning traffic, will convey to the driver two facts: one, that he may make the left turn; and two, that he must yield to the opposing traffic.

- 7.20 FALK, NORMAN, "New Technique For Illuminating Underpasses" *Traffic Engineering*, Vol. 35, No. 11, August, 1965, pp. 24-27 and 35-39.

Descriptor: underpass lighting.

This paper examines a new, basic technique for providing safety illumination for underpasses, and its various physiological, mechanical, and economic implications.

- 7.21 FIALA, E. "Zur Theorie der Leiteinrichtungen am Stassenrand." *Automobiltechnische Zeitschrift*, Vol. 65, No. 9, Sept. 1963, pp. 276-281.

Descriptor: markings.

Theory of roadside markings, reasons for deviation of vehicle from course of road and dependence of impact angle on speed; evaluation of flexible and rigid road markings and factors to consider in selection of type of markings.

- 7.22 FORBES, THEODORE W., SNYDER, THOMAS E., AND PAIN, RICHARD F. "Traffic Sign Requirements: I. Review of Factors Involved, Previous Studies and Needed Research." *Highway Research Record* No. 70, 1965, pp. 48-56.

Descriptors: signs - effectiveness, legibility, size, location, color.

This paper reports on a study of factors affecting highway sign effectiveness, legibility, "glance legibility," letter size, sign location, letter width and spacing, color, and contrast are considered.

- 7.23 "Freeway Lighting Posed Special Problem," *Street and Highway Lighting*, Vol. 14, No. 1, pp. 23, First Quarter, 1964, *Highway Research Abstract*, Vol. 34, No. 6, June, 1964, pp. 19-20.

Descriptor: freeway lighting.

This article discusses the problem of providing adequate light for both Lodge Freeway and service road levels.

- 7.24 GERLOUGH, D. L., AND WAGNER, F. A. "Improved Criteria for Traffic Signals at Individual Intersections - Interim Report," *Highway Research Board - National Cooperative Highway Research Program Report* 3, 1964, 36 pp.

Descriptors: signalization - design, timing; simulation model; bibliography.

Technical report of first year of research completed on project 3-5, "New Criteria for Designing and Timing Traffic Signals,"

established under National Cooperative Highway Research Program; all known past and present research having direct bearing on project was reviewed, and comprehensive bibliography was assembled; approximately 10% of entries were judged to bear particularly close relationship to work at hand and were therefore studied in greater depth; abstracts of these papers are given in appendix; digital computer simulation model was formulated to describe traffic performance at isolated intersections; model permits study of new control techniques and measures of effectiveness.

- 7.25 HONG, DR. H., "The Concept of Collapsible Sign Supports," (Technical Notes), *Traffic Engineering*, Vol. 37, No. 5, February, 1967, pp. 41-45.

Descriptor: collapsible sign supports.

The main emphasis of this conceptual study is placed on the development of ideas in the design of support joints, which are the main features of collapsible sign supports.

- 7.26 HARTMANN, E., "The Threshold of Disability Glare," *Light and Lighting*, Vol. 57, No. 3, March, 1964, p. 88. *Highway Research Abstracts*, Vol. 34, No. 7, July, 1964, p. 12.

Descriptor: glare criteria.

In this report, glare criteria are compared and measurements reported on the former.

- 7.27 HENSLEY, MARBLE J., SR., and VOLK, WAYNE N., "What Revisions Are Needed in Manual Signal Sections," *Traffic Engineering*, Vol. 36, No. 9, June, 1966, pp. 59-61.

Descriptor: signals -- colors.

This paper discusses the color of signals. The main colors: red, green, red and green arrows. Controversy over yellow or green arrows.

- 7.28 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.

Descriptor: traffic control devices.

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

- 7.29 HULBERT, SLADE, "Signing and Freeway Interchange Guide Signs-Final Report," *ITTE*, University of Calif., Research Report 42, Sept., 1965, Variously paged. *Highway Research Abstracts*; Vol. 36, No. 7, July, 1966, pp. 12-13.

Descriptors: motion picture technique; signing; driver guidance.

In this article a 16-mm motion picture technique was tested.

(Sign Tester) - Final Report," *ITTE*, University of California, Research Report 41, Sept. 1965, Variously paged. *Highway Research Abstracts*, Vol. 36, No.7, pp. 13-14, July, 1966.

- 7.30 HULBERT, SLADE AND WOJCIK, CHARLES, K., "Development of an Expeditious Method for Off-Site Testing of Freeway Sign Formats (Sign Tester) - Final Report," University of California, Research Report 41, Sept., 1965, Various pages. Highway Research Abstracts, Vol. 36, No. 7, pp. 13-14, July, 1966.
- Descriptor: sign tester.
- This article explains how the sign tester is used.
- 7.31 HUTCHINSON, JOHN W., AND KENNEDY, THOMAS W., "Safety Considerations in Median Design," Highway Research Record No. 162, 1966, pp. 1-29.
- Descriptors: medians; headlight glare; encroachment; delineation.
- This paper describes a study of the extent to which median width and cross-section can and should reduce headlight glare and delineate roadway alignment, the effect of median appurtenances on the safety of vehicle encroachment on the median and the extent to which this hazard can and should be decreased, and the width and cross-section needed for the stopping and recovery of encroaching vehicles and the prevention of cross-median accidents.
- 7.32 HUTCHINSON, JOHN W., AND LACIS, JANIS, H., "An Experiment with Evergreen Trees in Expressway Medians to Improve Roadway Delineation," Highway Research Record No. 105, 1966, pp. 85-98.
- Descriptors: median plantings; simulation; headlight glare; encroachment.
- This paper discusses simulated median plantings which were installed on selected portions of two Chicago expressways to determine whether they would significantly reduce the frequency of vehicle encroachment on the median. There was a significant reduction in the frequency of encroachment on the median of both expressways, with the greatest reductions occurring on or near curved alignment where the hazard of headlight glare from opposing vehicles had previously been greatest. The findings suggest the possibility of substantial improvement in the safety of divided highways through the development and use of median plantings appropriate to the needs of the driver under the various conditions imposed by roadway characteristics, driving conditions, and surrounding land use.
- 7.33 "Illuminated Motorway Warning Signs," Roads and Road Construction, Vol. 43, No. 507, March, 1965, p. 85-6.
- Descriptor: illuminated warning signs.
- Experimental remotely-controlled hazard warning sign system on 26 mi. of M. 5 (Birmingham-Bristol) Motorway in Worcestershire, England is featured; system consists of 22 illuminated signs, spaced at approximately 2 mile intervals on each roadway; each sign contains alternative legends - "Skid Risk," "Accident," and "Fog" in letters 1 ft. high; signs are about 11 ft. wide and mounted on steel platforms behind hard shoulders, their tops are about 12 ft. above level of road; they are designed so that legends are invisible until lights are switched on.
- 7.34 JAMES, E. W., "Reminiscences of a Traffic Pioneer: The Development of Interstate Signs," Traffic Engineering, Vol. 36, No. 9, June, 1966, pp. 50-51.
- Descriptors: interstate signs; colors;
- In the article, certain color schemes were worked out for the signs. The size was given careful consideration.
- 7.35 JAMES, J. G., "50 Years of White Lines," Roads and Road Construction, Vol. 42, No. 504, December, 1964, pp. 409-10. & 411-14.
- Descriptor: markings - development.
- Historical review of growth and developments of road markings in various countries and materials used for marking. 47 refs.
- 7.36 JOHANSSON, GUNNAR, AND OTTANDER, CHRIS., "Recovery Time After Glare," Scandinavian Journal of Psychology, Vol. 5, No. 1, pp. 17-25, 1964, Highway Research Abstracts Vol. 34, No. 9, September, 1964, p. 10.
- Descriptors: adaptation level; visibility; glare.
- In this report the changes in adaptation level due to glaring light in a night traffic meeting situation give no practically important deterioration of visibility.
- 7.37 JOHANSSON, GUNNAR, AND RUMAR, KARE, "Driver and Road Signs; A Preliminary Investigation of the Capacity of Car Drivers to Get Information from Road Signs," Ergonomics, Vol. 9, No. 1, pp. 57-62, January, 1966. Highway Research Abstracts, Vol. 36, No. 10, October, 1966, p. 2.
- Descriptors: driver communication - signs; capacity of driver.
- It was found that, under optimal conditions, the mean percentage of road signs noticed by drivers was 90%.
- 7.38 KEESE, CHARLES JOSEPH. "A Comparison of Thick Film and Thin Film Traffic Stripes." Thesis submitted to Texas A&M College, May, 1952.
- Descriptors: marking - traffic strips; visibility; durability.
- This paper is concerned with the effect of film thickness on the durability and visibility of paint stripes and with the performance of various types of thick film striping materials as compared to the performance of standard paint stripes.
- 7.39 KELLER, OLIVER, "Centralized Traffic Control by Signals & Television," Traffic Engineering, Vol. 36, No. 11, August, 1966, pp. 21-25.
- Descriptors: control - television, signals.
- This report deals with the merits of a centralized traffic control through television and signals, thus permitting observation of most traffic performances by way of television.

- 7.40 KNISLEY, HAROLD L., JR., "Wood Break-Away Posts Provide Safety for Motorists," Traffic Engineering, Vol. 34, No. 11, p. 17, August, 1964. Highway Research Abstracts, Vol. 34, No. 11., 1964, p. 7.

Descriptors: sign posts - wooden, break-away.

This report discusses the use and safety of break-away wood sign posts being used on I-90 in Pennsylvania.

- 7.41 MAYOR, RAFAEL CAL Y, "Mexico's Sign Program Aimed Toward International Markings," Traffic Engineering, Vol. 36, No. 2, November, 1965, pp. 25-27 and 55-56.

Descriptor: signs - uniformity.

This report deals with the efforts of the National Highway Commission to have uniformity in the road signs used on the American continent.

- 7.42 MCALPIN, GEORGE W., GRAHAM, MALCOLM D., BURNETT WILLIAM C. AND MCHENRY, RAYMOND R. "Development of an Analytical Procedure for Prediction of Highway Barrier Performance." Highway Research Record No. 83, 1965, pp. 188-200.

Descriptors: median barriers; guard rails; mathematical model.

This paper reports on the testing of median barriers, guard rails, and bridge rails to gain a fuller understanding of the forces involved between vehicle and barrier during collision. This work has resulted in the development of mathematical models for predicting the performance of current and proposed barrier designs. Barrier performance as predicted by computer solution of the mathematical model has been verified by subsequent full-scale crash tests.

- 7.43 MCDERMOTT, JOSEPH M. AND MCLEAN, CHARLES H. "Improving Traffic Flow at Transfer Roadways on Collector-Distributor Type Expressways." Highway Research Record No. 59, 1964, pp. 83-103.

Descriptors: markings; transfer roadways - signing geometrics.

This paper reports on the study of operational characteristics at an express-to-local transfer roadway and compares "before" and "after" pavement markings. The field methods and film analysis are presented. The studies pointed out various possibilities for improving traffic flow by eliminating or reducing certain undesirable movements at the merging and diverging terminals. Signing and geometric changes are suggested to improve the quality of traffic operations.

- 7.44 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.

Descriptor: uniform traffic control devices.

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

- 7.45 MILLER, ALAN J. "Computers in the Analysis and Control of Traffic." Traffic Quarterly, Vol. XIX, No. 4, October 1965, pp. 556-572.

Descriptors: computers; traffic analysis; traffic control.

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.

- 7.46 MOSKOWITZ, KARL. "Studies of Medians in Developed Areas." Highway Research News, No. 13, June, 1964, pp. 30-43.

Descriptors: medians - painted, curbed; accidents; opening spacing.

This paper reports a study in which accident data were compiled on 21 sections of a state highway, of which 12 had curbed medians and 9 had painted medians; all were in developed areas. The data were not conclusive either as to the relative merits of paint versus curbs, nor as to spacing between openings.

- 7.47 "New Road-Marking Material," Traffic Engineering, Vol. 34, No. 7, April, 1964, pp. 38-39. Highway Research Abstracts, Vol. 34, No. 7, July, 1964, p. 17.

Descriptor: marking material.

This report discusses Vervynyl, a new road marking material, and its application and use.

- 7.48 "New Roadway Lighting Standard," Traffic Safety, Vol. 64, No. 4, April, 1964, p. 11, Highway Research Abstracts, Vol. 34, No. 7, July, 1964, pp. 1-2.

Descriptor: roadway lighting standards.

This report tells about new recommended lighting levels based on studies conducted by the Illuminating Engineering Research Institute.

- 7.49 PERCHONOK, KENNETH, AND HURST, PAUL M. "The Effect of Lane Closure Signals upon Driver Decision-making and Traffic Flow." Institute for Research, Division of Highway Studies, Report No. 8, March, 1965, 11 pp. Highway Research Abstracts, Vol. 35, No. 10, October 1965, p. 12.

Descriptors: lane closure signals - traffic flow; driver decision-making.

The comparative effectiveness of two types of alerting signals for lane closure was studied in terms of traffic flow characteristics and driver decision-making (i.e. responsiveness, confusion, risk-taking predisposition, risk taking, and hazard.) In addition to improvements in terms of several traffic flow characteristics, results showed that the system affording the earlier warning was superior in terms of decreased driver confusion and hazard in gap acceptance.

- 7.50 PETERSEN, S. G. AND SCHOPPERT, D. W. "Motorists' Reactions to Signing on a Beltway." Highway Research Record No. 170, 1967, pp. 1-34.

Descriptors: signing; motorists' reactions.

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.

- 7.51 PINNELL, C. "The Value of Signal Phase Overlap in Signalized Intersection Capacity." TTI Research Project, Sept., 1962, 15 pp.

Descriptors: signalization; phasing - overlap cycle length; capacity.

This paper discusses the increase in capacity made possible at a signalized intersection by the use of phase overlaps. It also points out how phase overlapping improves the operating efficiency of signalized intersections by reducing cycle lengths to a range of 50 to 80 seconds, without sacrificing capacity.

- 7.52 POWERS, LAWRENCE D. "Effectiveness of Sign Background Reflectorization." Highway Research Record No. 70, 1965, pp. 74-86.

Descriptor: signing - background reflectorization.

This article reports on a study in which signs with different degrees of background reflectorization were compared by analyzing their effect on the ability of drivers to follow a test route to a given destination on controlled-access highways in a suburban area.

- 7.53 POWERS, LAWRENCE D. AND SOLOMON, DAVID. "Headlight Glare and Median White: Three Exploratory Studies." Highway Research Record No. 70, 1965, pp. 1-28.

Descriptors: medians; headlight glare; visibility.

Three study methods are explored for determining the effect of location of an opposing glare vehicle on visibility at night. In Study 1, both glare car and

target are stationary; in Study 2, both target and observer are stationary; while the glare car moves toward the observer; in Study 3, the target is self-luminous and both target and observer are stationary while the glare car moves toward the observer. The results show that the effects of glare decrease with increasing lateral separation of the glare car.

- 7.54 REX, CHARLES H., "Light Distribution for the Motorist," Traffic Engineering, Vol. 37, No. 4, January, 1967, pp. 37-43.

Descriptor: lighting.

Highway illumination will be examined as supplements to vehicle lighting, ultimately to develop an optimum night driving environment.

- 7.55 ROBINSON, CARLTON C., "Color in Traffic Control," Traffic Engineering, Vol. 37, No. 8, May, 1967, pp. 25-29.

Descriptor: traffic control - colors.

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

- 7.56 ROONEY, HERBERT A., "Reflective Markers: Epoxy, Polyester Buttons Aid Nighttime Visibility." Calif. Highways and Public Works, Vol. 42, Nos. 5-6, pp. 13-16, May-June, 1963. Highway Research Abstracts, Vol. 34, No. 2, pp. 3-4, February, 1964.

Descriptors: marking; visibility.

In this report buttons made of epoxy or polyester resins are discussed.

- 7.57 ROTH, WALTER J., AND DE ROSE, FRANK, JR., "Interchange Ramp Color Delineation and Marking Study." Highway Research Record No. 105, 1966, pp. 113-125.

Descriptors: ramp marking, signing, delineation; color coding.

This paper applies to two study locations where color coding was applied to edge-marking, 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 30 to 32 percent in erratic driving maneuvers. 90% of the motorists interviewed stated they received definite benefit from the color scheme.

- 7.58 ROWAN, NEILON J. "Approach-End Treatment of Channelization-Signing and Delineation." T.T. I. Interim Report on Project HPS-1-(27)-J. Highway Research Record No. 31, 1963, pp. 57-78.

Descriptors: signing; delineation; channelization; visibility; legibility.

This report deals with the signing and delineation of channelization and with the

effect of channelization and approach end treatment on certain characteristics of driver behavior. The delineation study was conducted to evaluate comparatively the visibility characteristics of four materials used to delineate channelizing island curbs. The signing study was conducted to evaluate the visibility and legibility characteristics of signs used in the approach-end treatment of channelization. The driver behavior study was concerned with driver tension and traffic speed in channelized areas.

- 7.59 ROWAN, N. J. "Marking the Approach-Ends of Channelization." TTI Bulletin No. 25, September, 1963, pp. 1-4.

Descriptors: channelization; marking.

This report deals with the problem of effectively warning the driver of islands and other obstructions in his path by appropriate approach-end treatment.

A stripping technique was developed using the "surface treatment" or "inverted penetration" construction procedures to produce a raised effect which was then painted and reflectorized.

- 7.60 ROWAN, NEILON J., JENSEN, HANS C. AND WALTON, NED E., "An Interim Report on a Study of Disability Veiling Brightness," T.T.I. Research Report 75-5, June 1967, 45 pp.

Descriptors: roadway lighting; disability veiling brightness.

This study, as a part of a project to develop design criteria for economical and functional roadway lighting, is concerned with the effects of system geometry on the DVB produced by various light sources. The specific objectives of this research were as follows: (1) to determine the DVB of selected roadway lighting systems of 1000 watt luminaires, (2) to determine the effect of mounting height on DVB for 400 and 1000 watt luminaires.

- 7.61 ROWAN, NEILON J., OLSON, ROBERT M., EDWARDS, THOMAS C, GADDIS, ALVIS M., WILLIAMS, THOMAS G. AND HAWKINS, D. L., "Impact Behavior of Sign Supports-II," A Staff Project Report, T.T.I. Research Report 68-2, September, 1965, 115 pp.

Descriptors: sign supports; impact behavior.

Studies involving the impact behavior of certain types of sign supports are described in this progress report. The progress report is presented in two parts. The first part of the report is based on observations of motion picture films of twenty seven crash tests conducted during the second year of research. Part B presents the results of a series of instrumented crash tests, comprising six in number, conducted to provide data for the development of a mathematical model to predict the impact behavior of sign supports. The development of a mathematical model expressing support post behavior is also described.

- 7.62 ROWAN, N. J., WILLIAMS, T. G. "Channelization" TTI Research Report 19-4, March, 1966, pp. 1-58.

Descriptors: channelization - signing, marking, delineation; accidents; visibility.

This article looks at several aspects of channelization: (1) delineation of channelization, (2) signing the approach-ends of channelization, (3) materials and methods of marking the approach-ends of channelization, (4) a study of accidents in channelized areas, and (5) a study of visual perspective of channelization and other roadway features.

- 7.63 SACKS, WILLIAM A., "The Effect of Guardrail in a Narrow Median Upon Pennsylvania Drivers" Hwy. Res. Record 83, 1965, pp. 114-131.

Descriptor: driving task model.

This paper discusses the study performed to identify and evaluate changes in traffic-stream flow characteristics resulting from the erection of a barrier of a 4-ft. median. Using the "Traffic Analyzer," a mobile recording laboratory, vehicular speed, lateral placement within the lane, and clearance between adjacent vehicles were measured both before and after the erection of the median barrier on the Schuylkill Expressway. The presence of the median had no reduction effect on vehicular speeds or densities. The results of the entire investigation coupled with other observations, led to the conclusions that although the median barrier does have a measurable effect on traffic flow characteristics it is not of an adverse nature.

- 7.64 SAMSON, CHARLES H., JR., ROWAN, NEILON J., OLSON, ROBERT M. AND TIDWELL, DANNY R. "Impact Behavior of Sign Supports," Texas Transportation Inst., Research Report 68-1, March, 1965, 45 pp.

Descriptors: sign supports; impact behavior.

Studies involving the impact behavior of certain types of supports for large signs are described in this report. The method of approach to the research reported herein was dependent upon the successful development of a full-scale crash test facility employing high-speed motion picture cameras to record the behavior of the sign support upon impact when struck by a standard size automobile. It is not intended that the studies presented herein reflect final research recommendations, but rather that they present a complete series of tests which have resulted in tentative designs that show promise of providing an economical method for reducing hazards.

- 7.65 SCHWAB, RICHARD N. "Night Visibility for Opposing Drivers with High and Low Headlight Beams." (Abridgment) Highway Research Record No. 70, 1965, pp. 87-88.

Descriptors: visibility; disability glare; headlights.

The relative visibility of two tasks which are typical of those encountered in the nighttime driving situation was explored using the visual task evaluator measure-

ment technique. The tasks were illuminated with either high or low headlight beams. An opposing vehicle was located at one of several longitudinal separations with the same beam configuration as that of the observer's to simulate a single approaching vehicle at one of four different median widths: Disability glare measurements were made with a Pritchard photometer and the overall visibility evaluated through an analytical procedure.

The two tasks studied were (a) a red retro-reflector on the rear of an unlighted, black car, parked 500 ft. from the observer on the right shoulder, and (b) a section of standard pavement stripe, 200 ft. ahead on the right-hand pavement edge.

The results are given in terms of a supra threshold factor. This factor is a measure of how many times above threshold the visibility of an actual target is.

- 7.66 SIELSKI, MATTHEW C., "Night Visibility and Traffic Improvement," *Traffic Engineering*, Vol. 36, No. 8, May, 1966, pp. 28-31.

Descriptor: lighting on freeways.

It has been the purpose of this article to elaborate upon a phase of traffic control that needs more attention. We need more application of techniques we know will reduce night accidents.

- 7.67 "Sight and Sound Alert Motorists." *Traffic Engineering*, Vol. 34, No. 12 Sept., 1964, p. 26.

Descriptors: freeway off-ramps; warning system - wrong-way drivers.

The Traffic Department of the California Division of Highways is experimenting with a new sight and sound warning system designed to alert wrong-way motorists on a freeway off-ramp. Evaluation of the current project will be made possible by use of a counter which records the frequency with which the warning signs are made operational by erring motorists. The time of day as well as the date will be recorded.

- 7.68 "A Standard For Adjustable Face Vehicle Traffic Control Signal Heads," *Traffic Engineering*, Vol. 36, No. 8, May, 1966, pp. 21-27.

Descriptor: traffic signal heads.

The purpose of this is to provide a guide for the preparation of minimum purchase specifications for adjustable face vehicle traffic control signal heads.

- 7.69 "A Standard For Traffic Signal Lamps," *Traffic Engineering*, Vol. 36, No. 8, May, 1966, p. 19.

Descriptor: traffic signal lamps.

The purpose of this standard is to provide a guide for the minimum purchase specifications for traffic signal lamps.

- 7.70 TIDWELL, DANNY R., AND SAMSON, CHARLES H. "Wind Tunnel Investigation of Nonsolid Sign Backgrounds." *Highway Research Record* No. 103, pp. 1-9, 1965.

Descriptors: nonsolid sign backgrounds; windloads.

This paper reports on the effects of wind on large signs. A feasibility study was made of six types of nonsolid backgrounds, with solid background as control. Specimens were tested in different speeds of wind at different angles. Results indicated that a lowered background is promising.

- 7.71 TINNEY, EDWARD I., "Traffic Striping and Pavement Markings." *Public Works*, Vol. 96, No. 5, p. 157, May, 1965. *Highway Research Abstracts*, Vol. 35, No. 10, October, 1965, p. 14.

Descriptors: pavement marking; maintenance; visibility.

This paper discusses the problem of maintaining adequate marking on pavement. Traffic line marking with thermoplastic in conjunction with reflective wedges seems to be promising for the ultimate visibility in high traffic density areas under every weather condition. Thermoplastic should last 10 to 20 times longer than solvent-placed paint. The cost of this particular type of marking (pavement) is discussed.

- 7.72 THOMPSON, J. A. AND FANSLER, B. I. "Economic Study of Various Mounting Heights for Highway Lighting." *Highway Research Record* No. 179, 1967, pp. 1-15.

Descriptors: highway lighting; cost effectiveness.

The purpose of this study is to investigate the cost effectiveness of various luminaire mounting heights and to present a method of evaluating alternate lighting designs that will lead to more economical highway lighting.

- 7.73 WAGNER, LOUIS C., AND HARDER, VIRGIL E., "Methods of Providing Information to Motorists on the Interstate System." *Traffic Quarterly*, Vol. XIX, No. 4, October, 1965, pp. 504-519.

Descriptor: driver communications.

This article sets forth two constraints which surround the interstate system and which therefore require a change in the concept of how information will be provided to motorists. A second section discusses the existing means which are used to provide information. A third section discusses potential means which may be used. Safety rest areas with information displays suggested as the best means of communications.

- 7.74 WALTON, NED E. "An Investigation of the Effects of Luminaire Mounting Height on Roadside Sign Placement and Visibility." A thesis submitted to Texas A&M University, August, 1966.

Descriptors: roadway lighting; sign visibility.

This paper was written to evaluate the effects of luminaire mounting heights on roadside sign placement and visibility; to measure sign brightness; background brightness, and disability veiling brightness associated with different luminaire mounting heights and to investigate their effects on sign visibility; to correlate results obtained with previous research findings.

- 7.75 WALTON, NED E., AND ROWAN, NELLON J. "An Interim Report on Roadside Visibility," TTI Research Report 75-3, August, 1966, 33 pp.

Descriptors: sign visibility; roadway lighting.

The specific objectives of this research were as follows: to evaluate the effects of luminaire mounting heights on roadside sign placement and visibility; to investigate sign brightness, background brightness, and disability veiling brightness associated with luminaire mounting heights and to investigate their effects on sign visibility; and finally to correlate results obtained with previous research findings.

- 7.76 WECKESSER, PAUL M., "Remote-Controlled Signs Cut Turnpike Accidents." American City, Vol. 80, No. 2, p. 118, Feb., 1965. Highway Research Abstract, Vol. 35, No. 5, May, 1965, pp. 2-3.

Descriptors: accident rate; warning signs.

This paper discusses the ability of remote radio-controlled warning signs to cut down on accident rate on any limited access roadway. These large illuminated signs display warning messages to advise motorists of fog, snow, ice or an accident ahead. The signs also make it possible to lower the speed limit by remote control from the normal 60 mph to a safe figure five seconds after the report of an accident or obstruction reaches the traffic control center.

- 7.77 WOJCIK, HENRY L., "Highway Lighting: Design Dilemma," Consulting Engineer, Vol. 22, No. 3, pp. 100-105, March, 1965. Highway Research Abstract, Vol. 34, No. 8, August, 1964, p. 2.

Descriptor: roadway lighting; design criteria.

This guide lists the specific illumination level to be provided on the pavement, the permissible illumination uniformity ratios, and some of the lighting equipment performance data to be included or considered in roadway lighting system design.

- 7.78 YOUNGBLOOD, WALTER P., "An Evaluation of Temporary Lane Marking Tape," (Technical Note) Traffic Engineering, Vol. 36, No. 8, May, 1966, pp. 42-44.

Descriptor: lane marking tape.

This study evaluates the use of temporary lane marking tape, primarily because of the ease of completely removing such tape. In the past, painted temporary markings necessitated grinding to remove the paint once the marking function was completed.

SECTION 8

ACCIDENT STUDIES AND HIGHWAY SAFETY

- 8.01 ANTHONY, F. L. "An Adequate Highway Safety Program." Presented to the 52nd Annual Road School, Purdue University, Lafayette, Indiana, March 28-31, 1966. Printed in the Engineering Extension Series, No. 123, pp. 11-20.
- Descriptor: highway safety.
- This paper discusses general opinions on the reasons for increasing highway fatalities; actions taken by various organizations to reduce the death toll; and safety requirements in design, legislation, operations, and automobile design.
- 8.02 BAKER, J. STANNARD. "Traffic Supervision and Road Safety." Presented to the 52nd Annual Road School, Purdue University, Lafayette, Indiana, March 28-31, 1966. Printed in the Engineering Extension Series, No. 123, pp. 21-26.
- Descriptors: highway safety; traffic supervision.
- This article discusses traffic law enforcement, traffic direction, traffic accident reporting and investigation, and the activities of non-police agencies. It is a rather general summary of these factors contributing to safety.
- 8.03 BAKER, WILLIAM T., AND SAWHILL, ROY B., "Automating Traffic - Accident Records," *Trend in Engineering*, Vol. 16, No. 2, pp. 14-18, April 1964. (Vol. 34, No. 8, August, 1965, p. 12).
- Descriptor: accident records - automation.
- A group of electronic-data programs was developed to assure a workable approach for agencies engaged in analyzing traffic accidents.
- 8.04 BALDWIN, DAVID M., "Accident Causes and Countermeasures," *Traffic Engineering*, Vol. 36, No. 5, March 1966, pp. 31-35.
- Descriptor: accident causes.
- In summary, a clear recognition of the concept that causes of accidents represent those factors which might have prevented the accident.
- 8.05 BLANCHE, ERNEST E., "The Roadside Distraction," *Traffic Safety*, Vol. 65, No. 11, pp. 24-25, 36-37, Nov. 1965. *Hwy. Res. Abstract*, Vol. 36, No. 6, June, 1966, p. 3.
- Descriptors: accidents - statistics, causes.
- Tells percentages of death tolls and causes of accidents.
- 8.06 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.
- Descriptors: access control; accidents.
- 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.
- 8.07 BROWN, RUSSELL I., "Needed: \$958 Million More for Traffic Safety," *Traffic Engineering*, Vol. 36, No. 5, Feb. 1, 1966, pp. 21-24.
- Descriptor: traffic safety - cost.
- Due to accidents and congestion, symptoms of deficient management, we are not getting our moneys worth for the \$187 billion highway transportation system we have. To have better management, \$958 million more annually would have to be spent. What is the reaction going to be among state legislatures, county commissioners, city councils - and taxpaying voters - who have been saying: "We can't afford it?" Now the taxpayers are changing their position and are saying in effect: "We can't afford not to."
- 8.08 BYINGTON, S. R. "Interstate System Accident Research," *Public Roads*, Vol. 32, No. 11, Dec. 1963, pp. 256-266.
- Descriptors: accidents; statistical analysis.
- Report of study comparing traffic accident experience on completed portions of interstate highway system with that on nearby highways, which formerly carried largest percentage of interstate traffic; included are data from 16 states for more than 1000 miles of Interstate system and nearby highways; results of comparison show that accident rates on Interstate System are about half as great as those on nearby highways and injury and fatality rates are about 1/3 as great; information collected on effect of traffic volume, analysis by manner of collisions, and importance of access control are summarized.
- 8.09 "California Tries to Stop Wrong-Way Freeway Entries," *Western Construction News*, Vol. 40, No. 7, p. 92, July, 1965. *Hwy. Res. Abstracts* Vol. 36, No. 3, March 1966, p. 8.
- Descriptors: signing - wrong-way driving; accident prevention.
- This explains the reason for new signs being installed on freeways to prevent accidents from wrong-way entries in California.

- 8.10 CAMPBELL, M. EARL "Highway Traffic Safety - Is It Possible?" Traffic Quarterly, Vol. XIX, No. 3, July, 1965, pp. 333-354.
- Descriptors: highway safety - history; cost-benefit, possibilities.
- This article presents a history of the highway safety campaign, reviews some factors of highway accidents, and discusses some possibilities of increasing highway safety. It covers the relationship of speed and safety, speed zoning, the human factor, the research program, and costs and benefits.
- 8.11 CARLQUIST, J. C. A., "Safe or Dangerous?" An International Comparison of Traffic Accident Figures," Traffic Engineering, Vol. 36, No. 11, Aug., 1966, pp. 31-35.
- Descriptor: accident study.
- This is a study of accident figures throughout the world in an effort to establish what is safe or unsafe. The conclusion is that you cannot compare the countries.
- 8.12 "Causes and Characteristics of Single Car Accidents: Pt. 1," California Highway Transportation Agency, Feb., 1965. Highway Research Abstracts, Vol. 34, No. 5, May, 1964, p. 4.
- Descriptor: one-car accidents - frequency and causes.
- This discusses the frequency and cause of one-car accidents.
- 8.13 CIRILLO, J. A. "Interstate System Accident Research - Study II," Highway Research Record No. 188, 1967, pp. 1-7.
- Descriptors: accidents; guardrails.
- This article is an interim report on a long term study relating accident experience on the Interstate System to its various geometric design characteristics. This portion of the study investigates the effects of guardrails on accident severity at bridge structures and sign posts and the effect of lateral clearance at bridge structures on accident occurrence and severity.
- 8.14 "Coding Accident Locations," Traffic Engineering, Vol. 34, No. 5, Feb., 1964, pp. 42-51
- Descriptor: accident location coding.
- This report deals with the need of a code system for the location of accidents to be included in the punch cards instead of the old method of only putting accident data on the cards. This will greatly benefit the study of accidents and will help point out recurrent intersections, also taking out the manual labor.
- 8.15 CORGILL, WILLIAM LOUIS, "Some Exploratory Thoughts Concerning the Philosophy of Traffic Accidents," Traffic Engineering, Vol. 36, No. 9, June, 1966, pp. 39-40.
- 8.15 Descriptor: accidents.
- This article is an accident study.
- 8.16 CRIBBINS, P. D., AREY, J. M., AND DONALDSON, J. K. "Effects of Selected Roadway and Operational Characteristics Upon Accidents on Multilane Highways." Highway Research Record 188, 1967, pp. 8-25.
- Descriptors: accidents; roadway and operational characteristics.
- This investigation was concerned with the effects of selected roadway and operational characteristics upon accidents on multilane highways. Attempts were made to correlate eight selected site characteristics, such as ADI volume, speed limit, and median width, with all injury accidents on site. A multiple regression analysis was performed. Prediction equations were developed to measure the effects of any new set of variables on injury accidents for a new site. The effects of certain roadway characteristics on the frequency of median-opening accidents were also investigated.
- 8.17 DEROSE, FRANK, "An Analysis of Random Freeway Traffic Incidents: Accidents and Vehicle Disabilities," Highway Research Record No. 72, 1965, pp. 58-87.
- Descriptors: Operations; freeway incidents.
- This paper states that the purpose of this study is to determine the frequency and character of random freeway traffic incidents and also to investigate those factors influencing the occurrence of these incidents. The study took place on the John Lodge Freeway in Detroit and the data for the study covered a one-year period from June 1, 1962, to June 1, 1963. Some reasons related to freeway incidents included: weather, pavement conditions, temperature, day of the week, time of day, etc.. The preliminary results indicate the degree of influence of these factors and provide an insight into the frequency, type, and character of random freeway incidents.
- 8.18 "Freeway Traffic Accident Analysis and Safety Study." TTI Report, June 15, 1958, pp. 1-23.
- Descriptors: freeway design; accidents; accident reporting.
- This report involves an analysis of the relationship between freeway design and accidents on freeways in the five largest cities in Texas - Houston, Austin, Dallas, Fort Worth, and San Antonio.
- A discussion on the accident reporting procedure is also included.
- 8.19 GALATI, J. V. "Median Barrier Photographic Study." Highway Research Record No. 170, 1967, pp. 70-81.
- Descriptors: markings; photographic techniques; accidents.
- This article reports on a study performed to identify damages to and to evaluate the effectiveness of the metal median

- 8.19 barrier on the Schuylkill Expressway, Philadelphia, in relation to accident occurrence, volume and geometric design, via the use of photography.
- 8.20 GARWOOD, F., AND STARKS, H. J. H., "Comparisons of Methods of Studying Accident Causation," Proceedings of a Convention on Road Accidents, Nov. 1965, pp. 22-27, 30-34, 43-48. Hwy. Res. Abstract, Vol. 36, No. 8, August, 1966, p. 4.
- Descriptors: accident causes; study methods
- In the article, they have a collection of statistics of the results of individual inquest into accidents.
- 8.21 GOLDSTEIN, LEON G., "Human Variables in Traffic Accidents: A Digest of Research," Traffic Safety Research Review, Vol. 8, No. 1, pp. 26-31, March 1964. Highway Research Abstracts, Vol. 34, No. 5, May, 1964, p. 1.
- Descriptors: accidents; human factors.
- This deals with the results of studies concerning certain psychological characteristics and accidents.
- 8.22 GWYNN, DAVID W., "Accident Rates and Controls of Access," Traffic Engineering, Vol. 37, No. 2, Nov., 1966, pp. 18-21.
- Descriptors: accidents; access control.
- It is a study comparing accidents, injuries, accident rates, etc. on highways with controlled access to those without access control.
- 8.23 GWYNN, DAVID W. "Relationship of Accident Rates and Accident Involvements with Hourly Volumes." Traffic Quarterly, Vol. XXI, No. 3, July 1967, pp. 407-418.
- Descriptors: accident rates; hourly traffic volume.
- This article investigates the relationship of accident rates and hourly volumes and the relationship of accident involvements, by passenger cars and trucks, with hourly volume.
- 8.24 HADDON, WILLIAM, AND KLEIN, DAVID. "Assessing the Efficacy of Accident Countermeasures" Traffic Quarterly, Vol. XIX, No. 3, July, 1965, pp. 321-322.
- Descriptor: accident prevention.
- This paper discusses accident prevention measures which either prevent potentially harmful forces from reaching the body or modify the force so that the damage is prevented or reduced.
- 8.25 HENAUAT, GILLES G., AND PERRON, HENRI. "Research and Development of a Guide Rail System for a High-Speed Elevated Expressway." Highway Research Record No. 152, 1966, pp. 36-65.
- Descriptors: accident analysis; guide rail system.
- This paper deals with the analysis of accidents on an elevated expressway in Montreal. It also investigates procedure, testing, results, analysis, recommendations, and an analysis of accidents after the construction of the new guide rail.
- 8.26 HUELKE, DONALD F., AND GIKAS, PAUL W. "Non-Intersectional Automobile Fatalities - A Problem in Roadway Design." Highway Research Record 152, 1966, pp. 103-119.
- Descriptors: accidents; roadside obstacles; roadway design.
- This paper reports on a study of the effect of roadside obstacles and roadway design on the number of accident fatalities.
- 8.27 "Human Factors in Highway Research to Promote Efficient Traffic Flow and Safe Motor Vehicle Operation." Highway Research News 19, June, 1965, pp. 37-40.
- Descriptors: human factors; traffic flow; highway safety.
- This paper reports on three major areas in which human factors research can promote more efficient traffic flow and safer motor vehicle operation. These three areas are:
1. Special psychological conditions that are peculiar to the highway user in his special environment;
 2. Communication in the highway - vehicle - driver system; and,
 3. Detailed analytical studies of the driving task in relation to degree of automatization.
- 8.28 HUTCHISON, A. L. "Traffic Engineering and Traffic Safety." Presented to the 52nd Annual Road School, Purdue University, Lafayette, Indiana, March 28-31, 1966. Printed in the Engineering Extension Series, No. 123, pp. 27-30.
- Descriptor: traffic safety.
- This article presents some general suggestions for increasing highway safety. The author suggests the best use of existing controls, control of traffic operations, pedestrian controls, and participation in research.
- 8.29 HUTCHINSON, JOHN W. AND KENNEDY THOMAS W. "Use of Accident Records in Highway Research." Highway Research News, No. 13, June, 1964, pp. 1-8.
- Descriptors: accident records and reporting.
- A study was made of the accuracy and completeness of accident reporting to determine whether or not existing accident records could be used in evaluating the

- 8.29 past performance of the various types of highway medians now in service throughout Illinois. Current accident reports and records for divided highways were compared with the results of a detailed field investigation of the evidence at the sites of all reported and unreported accidents involving the median. It was concluded that existing accident records would be of little use in evaluating the past performance of the various types of medians now in service throughout the State.
- 8.30 **JOHNSON, ROGER T.**, "Effectiveness of Median Barriers," Presented at the 44th Annual Meeting of the Highway Research Board, Jan. 11-15, 1965. Similar report in California Division of Highways, Traffic Dept., August, 1964, 50 pp.
- Descriptors: median barriers; accidents.
- This study was initiated to determine the effect of median barrier installation on all types of accidents. The construction and maintenance costs of the two barriers were also studied. Cross-median head-on accidents have been eliminated by barrier installation, but property damage accidents and injury accidents have increased. Fatal accidents have decreased at barrier locations.
- 8.31 **JOHNSON, ROGER T.**, "Freeway Fatal Accidents: 1961 and 1962". Highway Research Record No. 99, 1965, pp. 117-137.
- Descriptor: accident rates.
- Accidents and fatality rates for 1961 and 1962 for freeways are compared to those of conventional highways and streets in California. In 1962 there were 426 fewer people killed in California traffic accidents than there would have been if all travel had taken place on conventional highways and streets. For a given amount of travel, there are a little over one-half as many people killed on freeways as on other roads and streets.
- 8.32 **JOHNSON, ROGER T.**, "Freeway Pedestrian Accidents: 1958-1962." California Hwy. Transportation Agency, Traffic Bulletin, No. 9, June, 1964, 17 pp. (Abridgment) Highway Research Abstract, Vol. 35, No. 8, August, 1965, p. 8. Highway Research Record 99, 1965, pp. 275-280.
- Descriptor: freeway accidents.
- This article gives the statistical element of freeway pedestrian accidents. The statistics involve accidents on ramps, medians, during hours of the day, etc.
- 8.33 **LIND, BRUCE A., AND HONG, H.** "Traffic Accident Study on Milwaukee Expressway." Journal of the Hwy. Division, Vol. 91, No. HW1, Proc. Paper 4205, pp. 25-47, Jan. 1965. Highway Research Abstract, Vol. 35, No. 5, May, 1965, p. 3.
- Descriptors: accidents; design features; visibility; weather.
- Presented in this paper are correlations between traffic accidents and geometric design features of freeways. Visibility relationships, evaluation and revision of
- weaving section design, proper design of alignment at the junction of through lanes and interchange ramps, etc...are all important and needed. Weather, pavement surface, and light conditions are related to accidents in varying degrees.
- 8.34 **LUNDY, RICHARD A.**, "The Effect of Ramp Type and Geometry on Accidents." Highway Research Record No. 163, 1966, pp. 80-119.
- Descriptors: accidents; ramp types.
- 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 angle) do not seem to affect the accident rate.
- 8.35 **LUNDY, RICHARD A.**, "Effect of Traffic Volumes and Number of Lanes on Freeway Accident Rates," Hwy. Research Record 99, 1965, pp. 138-147.
- Descriptors: accident rates; volumes; number lanes.
- This study is based on 659 miles of California Freeway. The Freeway segments were grouped into three classifications. The average daily traffic count was taken from freeway segments with four lanes, six lanes and eight lanes. The accident rate seemed to increase as the segments with fewer lanes were analyzed. This relationship introduces the possibility of significantly reducing the total number of freeway accidents by increasing the number of traffic lanes, even though the increase is not required by traffic volumes.
- 8.36 **VOSTREZ, JOHN J. AND LUNDY, RICHARD A.**, "Comparative Freeway Study," Highway Research Record No. 99, 1965, pp. 157-199.
- Descriptors: accident rate, design.
- The primary purpose of this study in the first phase was to obtain information concerning freeway design characteristics as related to accident frequency. The emphasis is on the relative safety value of the various design features. Part II of the study attempted to analyze each section and explain why that section had an unusually good or poor accident history.
- 8.37 **LYNCH, FRANK L. AND KEESE, C. J.**, "Restoring Freeway Operation After Traffic Accidents." TTI Bulletin No. 28, pp. 5-18.
- Descriptors: accidents; freeway operation.
- This article reports on the effects of traffic accidents on freeway operation, and evaluates methods of reducing delays in restoring normal operation by means of efficient communication and access.

- 8.38 MATTHEWS, AUBREY, "Spot Icing Major Culprit in Winter Death, Injury Toll," *Traffic Engineering*, Vol. 35, No. 5, Feb., 1965, pp. 10-12.

Descriptors: injury and death toll; spot icing.

The fact that accidents related to icing conditions are increasing at a much faster rate than the average is a good indication that this is one area that deserves the immediate attention of traffic engineers dealing with highway safety.

- 8.39 MATTHEWSON, J. D. "The Traffic Accident Outlook," *Traffic Quarterly*, Vol. XVIII, No. 3, 1964, pp. 310-320.

Descriptor: accidents.

This article discusses possible reasons for a rising accident rate, the need for better accident records, and the importance of an interstate highway system.

- 8.40 MAY, JOHN F., "A Determination of an Accident Prone Location," *Traffic Engineering*, Vol. 34, No. 5, February, 1964, pp. 25-28.

Descriptor: accident prone location.

Presented in this report is a statistical method of determining an accident prone location, be it a highway intersection or a section of open highway. By comparing accident rates with the traffic volumes for a series of intersections or a series of a section of open highway, a regression line can be computed. The accident rates are defined as accidents per million vehicles per year at intersections and accidents per hundred million vehicle miles per year on sections of open highway. An accident prone location can be assumed to exist if its rate is greater than one standard deviation above the regression line. A three year accident history is the minimum time period to be used in making an accident study. This is to prevent the wastage of funds due to a single spectacular accident.

A study of the regression line for both intersectional accidents and accidents on the open highway reveal that an increase in traffic volume usually shows an increase in accident rates.

- 8.41 MCGLADE, FRANCIS S., AND ABERCROMBIE, S. A., "Accident Classification for Research Purposes," *Traffic Quarterly*, Vol. 19, No. 4, pp. 481-503, October, 1965. *Hwy. Research Abstract*, Vol. 36, No. 6, pp. 1-2, June, 1966.

Descriptors: accident prevention, and classification.

This article tells accident classification system has provided sound information for some phases of accident prevention research.

- 8.42 MERLO, A. L. "Automotive Radar for Prevention of Collisions," *IEEE-Trans on Indus Electronics and Control Instrumentation*, Vol. IECI-11, No. 1, Feb., 1964, p. 1-6.

Descriptors: accident prevention; automotive radar.

Design of radar used to provide dependable warnings to avoid collisions; C. W. Doppler radar, which incorporates scheme of RF phase comparison to distinguish opening from closing targets, has been road tested and observations are presented; proposed system is described which utilizes reflected radar signal from another automobile to control forward motion of vehicle upon which it is installed, frequency and phase analysis for range measurement AM/CW.

- 8.43 MICHAELS, RICHARD M. "Adapting the Highway to the Human Element" (Abridgment) *Highway Research Record* 79, 1965, pp. 56-57.

Descriptors: safety; human factors.

This article discusses the driver and his perception of his situation. Results of this research indicate that visual velocity information is the most significant perceptual dimension for the safe performance of the functions of driving. The article discusses highway situations which sufficiently confuse the driver that the safety factor is reduced.

- 8.44 MICHAELS, RICHARD M., "Two Simple Techniques for Determining the Significance of Accident-Reducing Measures," *Traffic Engineering*, Vol. 36, No. 12, September, 1966, pp. 45-48.

Descriptor: accident prevention.

This study deals with methods to reduce accidents through improvements and to see if they are worthwhile.

- 8.45 MITCHELL, RICHARD H., "Freeway Accidents and Slow-Moving Vehicles," *Traffic Engineering*, Vol. 37, No. 2, Nov. 1966, pp. 22-25.

Descriptor: accidents; slow-moving vehicles.

The study investigated accident rates, severity, types, and contributing violations on five sections of freeway.

- 8.46 MORIN, D. A. "Application of Statistical Concepts to Accident Data," *Highway Research Record* No. 188, 1967, pp. 72-79.

Descriptors: accidents; statistical analysis.

This paper describes statistical procedures that can be employed to assure data reliability under three situations: (a) the range of variability to be expected due to change in accident rates for highway segments with differing vehicle-miles of travel; (b) the minimum accident rate that would have to be observed to assure that an established critical accident rate was, in fact, exceeded; and (c) the amount of reduction in the number of accidents that would have to be experienced before it could be concluded that a safety improvement project definitely was an improvement.

- 8.47 MOSKOWITZ, KARL. "Studies of Medians in Developed Areas," *Highway Research News*, No. 13, June, 1964, pp. 30-43.

Descriptors: medians - painted, curbed; accidents; opening spacing.

This paper reports a study in which accident data were compiled on 21 sections of

- 8.47 a state highway, of which 12 had curbed medians and 9 had painted medians; all were developed areas. The data was not conclusive either as to the relative merits of paint versus curbs, nor as to spacing between openings.
- 8.48 MULLINS, B. F. K., KEESE, C. J., "Freeway Traffic Analysis and Safety Study," TTI Report E115-60, January, 1961.
- Descriptors: freeway accidents; design features.
- This report concludes that concentrations of freeway accidents generally involved major changes in vertical alignment, ramps, interchange elements, and fixed objects. Each of these design features is discussed concerning its relationship to accidents. The report also outlines an improved method of freeway accident reporting, as well as procedures for the analysis of accident data.
- 8.49 MULLINS, B. F. K., "Improving Freeway Traffic Accident Reporting," TTI Reprint No. 11 from Traffic Engineering, December, 1960, 7pp
- Descriptors: accident reporting; design, operation.
- This research deals with the development of two significant improvements in methods of reporting accidents. The methods of reporting have been developed in research investigating the correlation of safety with freeway design and operation. Advantages of these two improvement features, to enforcement officials and to engineering and research, have been demonstrated by trial use over approximately a year by several cities in Texas.
- 8.50 O'MARA, J. J., "Electronic Guidance for Highway Safety," Civ. Eng. (NY) Vol. 34, No. 10, Oct., 1964, p. 38-40.
- Descriptors: highway safety; electronic guidance.
- Need for research to develop mechanical and electronic controls for cars on arterial roads is emphasized and method of electronic control outlined in which cars would be guided by cables buried in center of lanes, or other cables providing for access, egress, and passing; safe intervals are maintained by electronic devices that can act on engines and brakes; increased use of mass traffic media is also recommended.
- 8.51 PETERSON, A. O., AND MICHAEL, H. L., "An Analysis of Traffic Accidents on a High-Volume Highway." Presented to the 51st Annual Purdue Road School, March 29-April 1, 1965. Printed in the Engineering Extension Series, No. 119, pp. 208-239.
- Descriptors: statistical analysis; models.
- This is a report on an accident study from Jan. 1, 1961 to Dec. 31, 1963 on the Lafayette-West Lafayette (Indiana) Bypass. Equations covering the data are developed.
- 8.52 PRIEST, R. V., "Statistical Relationship Between Traffic Volume, Median Width, and Accident Frequency on Divided-Highway Grade Intersections," Highway Research News No. 13, 1964, pp. 9-20.
- Descriptors: medians; accident frequency; volume; intersections.
- This paper presents charts tabulated from 975 accidents, using statistics to explain the relationship between median width, traffic volume, and accident frequency. Uses of the charts include:
1. Estimating the number of accidents which will occur at a given grade intersection in a future period.
 2. Correcting for the influence of volume differences when comparing one grade intersection accident rate with another.
 3. Correcting for the influence of traffic exposure when comparing median width with accident frequencies.
- 8.53 RADKE, M. L., "Freeway Ramp Control Reduces Frequency of Rear-End Accidents," TTI Project Report No. 24-21, Nov., 1966, 24 pp.
- Descriptors: ramp controls; rear-end accidents; level of service; entrance ramps; geometric design, and control of traffic flow.
- 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 location, geometric design, "roller coaster" effect of freeway grades, and illegal entrances to the freeway.
- Results indicated that the ramp control system reduced both the frequency of 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.
- 8.54 "Research on Road Safety," Gt. Britain, Dept. of Scientific and Industrial Research, Road Research Laboratory, Available from British Information Services, 602 pp., 1963, Highway Research Abstracts, Vol. 34, No. 8, Aug., 1964, p. 4.
- Descriptor: road safety.
- The main purpose of this book is to collect the results of work carried out at Traffic and Safety Department of the Road Research Laboratory, though, to make the book more comprehensive, the results of some investigations carried out elsewhere are included.

- 8.55 ROTMAN, MORRIS. "Proposal for a Uniform Traffic Accident Report." *Traffic Quarterly*, Vol. XXI, No. 3, July, 1967, pp. 419-434.

Descriptors: accident reporting and analysis.

This article discusses the need of uniform traffic accident report to standardize traffic accident data. Existing forms are reviewed and a statistical traffic accident report is presented. This report incorporates the best features of the existing forms. The analysis of traffic accident data is discussed.

- 8.56 SCHLESINGER, LAWRENCE E., AND MYRICK, RICHARD. "Driver Improvement or System Improvement?" *Traffic Quarterly*, Vol. XVIII, No. 1, 1964, pp. 92-104.

Descriptor: traffic safety.

The general viewpoint of this article is that driver improvement can best be accomplished by improving the methods of management of those organizations responsible for traffic safety.

- 8.57 SEBURN, THOMAS J., "Relationship Between Curb Uses and Traffic Accidents." *Traffic Engineering*, Vol. 37, No. 8, May, 1967, pp. 42-47.

Descriptor: curb use and traffic accidents.

The purpose of this study was to explore in as much detail as possible, the relationship between curb uses--parking, loading, and standing--and traffic accidents.

- 8.58 SMITH, RICHARD N., "The Reporting Level of California State Highway Accidents." *Traffic Engineering*, Vol. 36, No. 9, June, 1966, pp. 20-25.

Descriptor: accident reporting.

The study procedures developed in this pilot study were fully sufficient to make an adequate and accurate search for accident reports with a minimum of effort.

- 8.59 SMITH, RICHARD N., "Surveillance of Accident Locations by Electronic Processing Methods." *Highway Research Record* No. 188, 1967, pp. 90-126.

Descriptors: accident surveillance; reporting; computer; statistical procedures, systems.

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 for 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.

- 8.60 SMITH, W. C. AND VOSTREZ, J. J., "Evaluation of Minor Improvement Projects" *Highway Research News* No. 13, June, 1964, pp. 21-29.

Descriptors: accident prevention; lighting; marking; cost effectiveness.

This report makes categorical comparisons of minor improvement projects. The reports were compared by cost versus net accident reduction for one year before and one year after the improvement. The reports indicate:

1. Minor improvement projects have been successful in reducing accidents at problem locations.
2. Safety lighting, delineation and protective guard railing appear to be very effective low-cost improvements.

- 8.61 "Surprise for Wrong-Way Driver," *Better Roads*, Vol. 34, No. 9, Sept., 1964, p. 31.

Descriptor: accident prevention - wrong-way driver.

Warning device is described designed as a part of experimental project by California Div. of Highways Traffic Dept. in attempt to reduce accidents caused by wrong-way drivers; device is activated by detector in pavement that is sensitive to wrong-way movement.

- 8.62 TAMBURRI, THOMAS N., THEOBALD, DAVID J., AND RICE, A. J., "Wrong-Way Driving (Phase II)." *Highway Research Record* No. 151, 1966, pp. 41-98.

Descriptor: accidents - wrong-way drivers.

The article reports on a study of wrong-way driving accidents on California freeways. Trends in age, sobriety, time of day, location, origin of wrong-way entry, and type of off-ramp were determined. The following remedial measures were tested; painted pavement arrows, spike barriers, sign and pavement markings, and an automatic sign-horn-light device.

- 8.63 TAMM, QUINN, "For Greater Traffic Safety," *Traffic Engineering*, Vol. 37, No. 8, May, 1967, pp. 23-24.

Descriptor: traffic safety.

It discusses the importance of a joint police-engineer team approach is clearly evident in the research area.

- 8.64 TAYLOR, WILLIAM C., AND FOODY, THOMAS J., "Ohio's Curve Delineation Program--An Analysis," *Traffic Engineering*, Vol. 36, No. 9, June, 1966, pp. 41-45.

Descriptors: accident prevention; curb delineation.

The objective of this research was to determine the parameters to be used in establishing warrants for curve delineation. The basis for evaluating the effectiveness of delineation was the reduction in accident.

- 8.65 "Traffic Control and Roadway Elements - Their Relationship to Highway Safety." *Automotive Safety Foundation*, Washington, D.C., 1963, 124 pp.

Descriptors: accidents; design; control.

Review and analysis of engineering studies conducted in the United States and abroad

- 8.65 on questions dealing with relationship of traffic accidents to roadway design and traffic control; report consists of summary of research and bibliography of pertinent literature, summary cites representative documents which embody different methods of study and different conclusions, theories, and findings appropriate to each subject.
- 8.66 VANDERSTEMPEL, T. M., "A Device to Lessen Injuries in Fixed Object Collisions." *Traffic Engineering*, Vol. 37, No. 2, Nov., 1966, pp. 32-36.
 Descriptor: fixed objects collisions.
 Tells about a device that will collapse when hit.
- 8.67 VENABLE, CLINTON A., "Statewide Safety Program." Presented to the 52nd Annual Road School, Purdue University, Lafayette, Ind., March 28-31, 1966. Printed in the *Engineering Extension Series*, No. 123, pp. 44-56.
 Descriptors: highway safety; highway design.
 This article reviews current safety programs and discusses several design concepts which might increase safety.
- 8.68 WHITEHEAD, ROBERT S., "State and Local Safety Program." Presented to the 52nd Annual Road School, Purdue University, Lafayette, Ind., March 28-31, 1966. Printed in the *Engineering Extension Series*, No. 123, pp. 57-64.
 Descriptor: highway safety program.
 This article discusses the efforts of the Indiana State Highway Commission to increase highway safety. It considers maintenance, traffic, safety in construction areas, and design.
- 8.69 WHITTON, REX M., "Entire Bureau of Roads Program Aimed Towards Improved Safety." *Traffic Engineering*, Vol. 35, No. 9, June, 1965, pp. 13-15, 53-55.
 Descriptors: traffic safety - planning, location, design, construction and maintenance.
 This article discusses the primary aims of the Bureau of Roads. The improvement of traffic safety and of traffic service are primary objectives of the Bureau and play a vital part in the planning, location, design, construction and maintenance of highways. Improvement of traffic safety and of traffic service go hand in hand.
- 8.70 WHITTON, REX M., "The Role of Highway and Traffic Engineering and Highway Safety." *Traffic Quarterly*, Vol. XIX, No. 1, Jan., 1965, pp. 3-16.
 Descriptor: highway safety.
 This article discusses specific highway improvements which could increase highway safety. Particular attention is paid to the economy of these improvements. Several new programs of the Office of Highway Safety are discussed. Highway-vehicle interaction is studied.
- 8.71 WILLIAM, EARL C., JR., "Evaluating Safety," *Traffic Engineering*, Vol. 35, No. 6, March, 1965, p. 17.
 Descriptor: measure of safety.
 It is believed that further testing of the concept of a "measure of hazard" will develop a traffic engineering tool with wide application, which will enable traffic engineers to compare the relative safety of operation of various facilities and isolate these facilities in the greatest need of improvement.
- 8.72 WILSHIRE, ROY L., KEESE, C. J., "Effects of Traffic Accidents on Freeway Operation." *TTI Bulletin* No. 22, April, 1963, pp. 3-13.
 Descriptors: freeway accidents; traffic control; accident reporting.
 This report was designed to study the effects of traffic accidents on freeway operation in the interest of improving the level of service, to analyze and improve traffic control methods employed during accident investigation, and to promote better freeway accident reporting and greater interest among investigating personnel so that complete accident information suitable for engineering analyses could be provided.
- 8.73 WILSON, JAMES E., "California Fog Study Cuts Accidents," *Traffic Engineering*, Vol. 35, No. 11, August, 1965, pp. 12-14 and 44-55.
 Descriptors: visibility; accidents.
 This report summarizes the experience acquired to date by the Highway Transportation Agency in a study of various means of giving advance warning to drivers of motor vehicles of the need for greater alertness and caution in driving during periods of reduced visibility. The purpose of the study is to find means of preventing, insofar as possible, the multiple vehicle accidents associated with reduced visibility.
- 8.74 WILSON, JAMES E., "California's Reduced Visibility Study Helps Cut Down Traffic Accidents When Fog Hits Area," *Traffic Engineering*, Vol. 35, No. 11, pp. 12-14, 44, August, 1965. *Hwy. Res. Abstract*, Vol. 36, No. 2, Feb., 1966, p. 2.
 Descriptors: visibility; accidents.
 This report summarizes the experience acquired to date by the Highway Transportation Agency in a study of various means of giving advance warning to drivers of motor vehicles of the need for greater alertness and caution in driving during periods of reduced visibility.
- 8.75 WOHL, MARTIN, "A Philosophy for Accident Prevention." *Traffic Engineering*, Vol. 55, No. 8, May, 1965, pp. 21, 44-48.
 Descriptor: accident prevention.
 This article stresses the need for the elimination of traffic accidents. Some of the goals set forth by the author include: driver control, control through inter-vehicular communication, control through roadway design, through mechano-electrical developments, through limitation, etc.

SECTION 9

MISCELLANEOUS

A. SURFACE STREETS

- 9.01 BECKMANN, MARTIN J., "On the Theory Flow in Networks." *Traffic Quarterly*, Vol. XXI, No. 1, January, 1967, pp. 109-116.

Descriptors: traffic flow; networks.

This article discusses problems in developing a theory of transportation network which might predict properties of traffic flow in various segments of the network.

- 9.02 CARROTHERS, J. A., "Computer Control Systems" *Traffic Engineering*, Vol. No. 6, No. 12, Sept., 1966, pp. 49-50.

Descriptor: computer control systems.

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

- 9.03 CRIBBINS, PAUL D., "Location of Median Openings on Divided Highways." *Traffic Engineering*, Vol. 37, No. 7, April, 1967, pp. 17-25.

Descriptor: medians - opening location.

This article was discussing median openings or crossovers, at various locations along the facility to permit vehicles to reach abutting roadside development or to reverse their direction of travel.

- 9.04 DeROSE, FRANK, "Reversible Center Lane Traffic System-Directional and Left-Turn Usage." *Highway Research Record* No. 151, 1966, pp. 1-17.

Descriptors: traffic flow; reversible lanes.

This paper thoroughly discusses the change of a six-lane street with three lanes of traffic travelling each direction into a five-lane street with the middle lane designated for direction-reversal during peak traffic hours.

- 9.05 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.

Descriptors: accidents - statistical analysis; design; control.

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 decreases,

ed, and the number of heavily used driveways per mile decreased.

- 9.06 PINNELL, C., "Optimum Distribution of Traffic over a Capacitated Street Network." *TTI Research Report* No. 24-2, October, 1964, 77 pp. Similar study by PINNELL, C., Dissertation, Texas A & M University, 1964.

Descriptors: system control; network optimization.

This article is concerned with computer treatment of freeway and arterial distribution of traffic during peak traffic hours.

This article is concerned with the development of computer programs using linear programming techniques to obtain optimum distribution of traffic over portions of a street network. The traffic inputs are the origins and destinations, street network, and capacitated links. Travel time cost based on volume considerations and length of travel is the criterion which is optimized.

- 9.07 ROWAN, NELSON JOYCE, "A Study of the Effect of Posted Speed Limits on Traffic Speeds," a Thesis, submitted to the Graduate School of the Agricultural and Mechanical College of Texas, August, 1959, 91 pp.

Descriptor: traffic speeds.

The research reported in this thesis consists of a comparative study of "before" and "after" conditions in an effort to evaluate the effect of posted speed limits on traffic speeds. This study is in the initial phase of research project (RD.17). Study locations were selected from Texas Highway Dept. Districts. The data obtained consisted of strip maps. Also speed meters employing the radar principle were adopted by the Texas Highway Department. Conclusions were drawn from the research explaining speed signs effect on different areas of traffic speed.

- 9.08 THORPE, JOHN D., "Off-Center Street Operation in Melbourne," *Traffic Engineering*, Vol. 36, No. 11, Aug., 1966, pp. 26-30.

Descriptor: operation.

This article describes the various ways in which off center operation on narrow urban arterials is being accomplished and how some particular problems were overcome.

- 9.09 TREADWAY, T. B., "An Analysis of Travel Speed and Delay on a High-Volume Highway." *Joint Highway Research Project*, No. 10, Purdue University, Lafayette, Indiana, June, 1965, 90 pp.

Descriptor: traffic flow.

The paper is a report of a study made to identify the locations of delays on a bypass, to determine the significant factors causing these delays, and to make recommendations for improving the flow of traffic. Factor analysis and multiple linear regression techniques were applied to express overall travel speeds and delays as functions of factors and variables that

were descriptive of the traffic stream, roadway geometry, and roadside development.

- 9.10 WEINER, MELVIN M., "Directional Traffic Flow" *Traffic Quarterly*; Vol. XX, No. 4, October, 1966, pp. 589-608.

Descriptors: traffic flow; road networks; topological concepts.

In order to apply the favorable one-way-street experience of United States to a larger number of road networks, a scientific method is needed for determining the feasibility of unidirectional traffic flow in a road network of arbitrary geometry.

The accessibility of one-way streets in road networks of arbitrary geometry is determined by utilizing topological concepts. Trees and independent cycles are utilized to orient the roads of a unidirectional road network so that it is strongly connected. Evaluation of certain geometric parameters in the topological graph of an arbitrary road network is suggested for determining the potential feasibility of unidirectional traffic flow. The one-way-street experience of the U.S. is summarized. Some of the differences between topological graphs and directional flow graphs are reviewed.

- 9.11 YARI, S. S., "Sensitivity of a Traffic Network," *Journal of the Franklin Institute*, Vol. 278, No. 6, pp. 371-382, Dec., 1964. *Highway Research Abstracts*, Vol. 36, No. 2, p. 1, Feb., 1966.

Descriptors: networks; capacity.

The sensitivity of a traffic network is defined for investigating the variations of the terminal capacities due to the decreases of the capacities of individual elements.

B. ECONOMICS, BENEFITS AND LAND USE

- 9.12 ADKINS, W. G., "Effects of the Dallas Central Expressway on Land Values and Land Use." TTI Research Project 101, Sept., 1957, 87 pp.

Descriptors: land prices, tax valuations, land use.

This report presents the findings of a study of land values and land use along a 5.4 mile section of Dallas' Central Expressway. The "before-and-after" approach was used in the study with comparative control areas to isolate the expressway's influence. Changes in land values in the study areas and control areas during the period of influence of the expressway were measured. Differences in the changes in study and control areas were attributed to the expressway's influence. Although there are indications of some early negative influence on market values, they are more than compensated for by substantial increases in property values in later years. Positive benefits were greatest in areas abutting the expressway and extended 6 to 8 blocks from the facility. Land use in abutting properties was greatly altered and a tremendous potential for further change is

evident. Attitudes of businessmen and residents in the study area were very favorable. It is hoped that the results of this and similar studies will provide an improved basis for appraisal techniques.

- 9.13 ADKINS, WILLIAM G. and TIEKEN, ALTON W., "Economic Impacts of Expressways in San Antonio." TTI Bulletin No. 11, TTI Research Project 101, August, 1958.

Descriptors: economy; growth; land use; land value.

This article reports on a study of the effects of a 3.7 mile expressway near downtown San Antonio on land values and land uses. To determine the magnitude of expressway impacts on land values, real estate prices in study areas and in presumably nonaffected control areas were compared for periods before and after the expressway was constructed. Net differences in changes in prices in study and control areas were taken as expressway effects. Results of the study indicate that only one-family dwellings were negatively affected by the expressway construction. All other classes of property in the vicinity of the expressway experienced significant net increases in value. Land use changes were not significant. This study reflects only the earliest impact of the expressway. Somewhat different results might be obtained after the passage of additional time.

- 9.14 ASHLEY, ROGER H., and BERARD, WILLIAM, "Interchange Development Along 180 Miles of I-94," *Highway Research Record* No. 96, 1965, pp. 46-58.

Descriptor: interchange development.

All interchanges on 180 miles of freeway are analyzed. The interchanges are classified in relationship to the community and guidelines are set up for predicting benefits. For each classification the degree of development, the observed land values and the expected land values are given. Business success of service stations and motels in relationship to an interchange classification is also analyzed.

- 9.15 BAKER, ROBERT F., "Highways and Economic and Social Changes." *Economics and Requirements Div., Office of Res. and Development*, U. S. Bureau of Public Roads, Nov., 1964, 221 pp. *Highway Research Abstract*, Vol. 35, No. 7, July, 1965, p. 10.

Descriptors: economic study; highway interchanges.

The results of more than 100 economic impact studies in which state highway departments, universities and the U.S. Bureau of Public Roads have cooperated are analyzed. A list is also given of additional economic studies which have become available and other research which has been started since 1961 on the impact of highway interchanges on adjacent areas and related studies. The dramatic changes wrought by highways on people, homes, businesses, and land are discussed.

- 9.16 FRANKLAND, BAMFORD, "Community Effects upon Remainder Parcel Valuation." Highway Research Record No. 54, 1964, pp. 93-100.

Descriptors: economy; construction of freeways.

These studies are directed toward evaluating the community service component of freeway impact as a tool in the planning process. Three interrelated hypotheses are being tested, including (a) the general effect of a freeway on a community is to reinforce pre-existing trends; (b) the specific location of a freeway may accelerate or retard the pre-existing trends; and (c) to the degree that a freeway affects growth within a community, it will to an equivalent degree affect the value of a given piece of property, plus or minus any other effects which may be attributed to the physical aspects of the improvement.

- 9.17 BAYCU, ORHAN, "Investment Analysis by Computer Methods for the State Trunk Highway System in Wisconsin." Highway Research Record No. 143, 1966, pp. 48-61.

Descriptors: investment analysis, computers.

This article explains the so-called "investment analysis approach" which establishes needs from the relationship that exists between highway investments remaining in service and travel requirements. This paper constitutes Part I of a two-part investment analysis for the State Trunk Highway System in Wisconsin, undertaken, for the first time, with computer methods. The developed procedure given here is an introduction to the computer approach in estimating remaining cost in highways, and is intended to replace tedious computations now done manually. Using this new procedure, Wisconsin's backlog of more than twenty years in remaining cost records for the State Trunk Highway System has been eliminated, and possibilities have been created for the evaluation of highway needs on a 100% sample basis, which otherwise would have been impossible.

- 9.18 BEVIS, HOWARD W., "Estimating a Road-User Cost Function from Diversion Curve Data." Highway Research Record No. 100, 1965, pp. 47-54.

Descriptors: road-user costs; diversion curve.

A theory and a methodology are presented for estimating a road-user cost function using diversion curve data. The theory of diversion curves is presented as being a probability density function with normal distribution. The point in the density function associated with a given proportion of freeway usage is related to a generalized cost difference equation describing the comparative costs of using the freeway as opposed to the best alternate. The parameters of the cost function are then derived using regression techniques. The road-user cost equation derived from this analysis agree quite well with theoretical predictions and with results obtained from other studies

where relationships between the various components of road-user cost and speed of travel have been derived and priced out to obtain a user cost function.

- 9.19 BUFFINGTON, JESSE L. and ADKINS, WILLIAM G., "A Study of Eighteen Remainder Parcels Along Houston's Gulf Freeway." TTI Pilot Study, March, 1961, pp. 5-59.

Descriptors: economy; right of way; land value.

This study discusses 18 case histories involving partial taking of pieces of property for right of way in building the Gulf Freeway. The case histories were investigated to determine a better predictability for individual remainders, and to demonstrate detailed analytical procedures for making remainder studies. Emphasis was placed on the relative value of the remaining portions of the land before and after the freeway was built.

- 9.20 BUFFINGTON, JESSE L., "An Economic Impact Study of Interstate Highway 35E on Waxahachie, Texas." TTI Research Report 4-6, March, 1966.

Descriptor: economic impact.

The major effects of Interstate Highway 35E bypass on land values, land use, business activity, general travel habits, and general community development in the Waxahachie study area are summarized:

1. Generally, the area has benefited economically.
2. Land Values in the area increased.
3. Lane changing to a "higher use" commanded a higher value.
4. Retail business remained good on the old route.
5. Waxahachie experienced considerable economic growth.

- 9.21 BUFFINGTON, JESSE L., "Restudy of Changes in Land Value, Lane Use, and Business Activity Along a Section of the Interstate Highway 35 in Temple, Texas." TTI Research Report 4-5, Dec., 1964.

Descriptors: economic impacts; land use.

The effects measured and analyzed in the report are presented in terms of changes in land values, land uses, and business activities along the old route (US 81) and the New Route (IH 35) which bypassed Temple in 1955. The findings are:

1. Lane values in the study area, encompassing the IH 35 bypass, increased rapidly in the "after construction period" as compared with the control area.
2. Land use changed radically after the bypass was constructed.
3. In business, the freeway apparently reduced business at first but the depression did not continue.
4. Traffic serving business on the old route had an initial depression of business which did not last.
5. Nontraffic serving retail businesses on the old route had an increase in business after the freeway took heavy through-traffic off their street.

- 9.22 BUFFINGTON, JESSE L., "A Study of the Economic Impact of Interstate Highway 20 on Merkel, Texas." TTI Research Report 4-7, April, 1966.

Descriptor: economic impact.

The economic effects of the new route (IH20) on Merkel were measured and analyzed in terms of changes in land uses, business activities, travel habits, and general community developments. The results of these findings are:

1. Overall land values in the study area increased; the values increased more north of old U.S. Highway 80 in the vicinity of IH 20 than south of the old route.
2. Significant commercial and residential land use changes occurred.
3. Businesses experienced a significant increase in gross sales. The new highway adversely affected old traffic serving businesses located on the old highway.
4. Travel habits of Merkel residents changed considerably.
5. Economic indicators showed general community development.

- 9.23 BURTON, ROBERT C. and KNAPP, FREDERICK D., "Socio-Economic Change in Vicinity of Capital Beltway in Virginia." Highway Research Record No. 75, 1965, pp. 32-57.

Descriptor: socio-economic impact.

The basis of this report is a study of changing economic and social factors in the vicinity of the Virginia section of the Capital Beltway. The investigation is designed as a "before" and "after" study to determine over a period of time changes in land and real property values, land uses, traffic patterns, travel habits and residents, and business activity. Only the before portion of the study has been completed. Only the most obvious changes are discussed since the study has not been completed.

- 9.24 CARUTHERS, ORVILLE E., "Use of Aerial Photography in the Kansas Courts." Highway Research Record No. 65, 1965, pp. 116-128.

Descriptors: aerial photography; property values.

This article discusses the use of aerial photography in determining land value of adjacent property before and after highway projects.

- 9.25 CHERNER, MORRIE, "Property Values as Affected by Highway Landscape Developments." Highway Research Record No. 53, 1964, pp. 4-7.

Descriptors: property values; landscaping.

The purpose of this paper is to discuss intense landscape treatment limited to the expressway system. Three available avenues of approach to obtain cogent facts and data were pursued. The prime target was Edens Expressway in Chicago. Data was compiled, however, for portions of three expressways. Property values along these roads have increased from 100 to 500 per cent; residents are cognizant of

the landscaping and will increase their appreciation of it as the plants mature because of the avenues of research.

- 9.26 ST. CLAIR, G. P., TODD, T. R., and BOSTICK, THURLEY A., "The Measurement of Vehicular Benefits." Highway Research Record No. 138, 1966, pp. 1-27.

Descriptor: vehicular benefits.

This paper is a by-product of the differential-benefit study, which was one of the highway cost allocation methods used in an earlier study. Until its later stages, the differential benefit work was carried on by Paul J. Claffey, whose effective work in this field is attested to by a number of publications discussing the methods and findings of several sub-projects of the differential-benefit study. There remains only a mopping-up operation in which we examine what was produced in the study and what we have learned that may be of value for such work in the future.

- 9.27 COYLE, JOHN J., DANSEREAU, H. KIRK, FREY, J. C., and PASHEK, R.D. "Interchange Protection and Community Structure", Highway Research Record No. 75, 1965, pp. 62-74.

Descriptors: land use; interchange development.

This paper sets forth a general framework of research for interchange locations in rural and suburban areas. Major emphasis is placed on the development of an empirical model for land-use at planning interchanges. This recognizes that land use will alter both the practical capacity of the interchange and the volume of traffic using it. The model may be expanded to include other types of land management units, thereby making it more comprehensive and more generally applicable.

- 9.28 CRIBBINS, PAUL D., HILL, WILLIAM T., and SEAGRAVES, HAROLD O., "Economic Impact of Selected Sections of Interstate Routes on Land Value and Use." Highway Research Record No. 75, 1965, pp. 1-31.

Descriptor: economic impact.

This study is an attempt to ascertain the economic effects of controlled-access facilities in North Carolina on surrounding property values and development. Techniques used to isolate economic influence of highways include the before-and-after method in combination with a multiple regression analysis for each period. Results of the analysis indicated an increase within all sites of the average unit price of property. The statistical analysis indicated that the investigated highways have had no measurable effect on development within the study areas.

- 9.29 CURY, DAVID A., "Use of Marginal Cost of Time in Highway Economy Studies." Highway Research Record No. 77, pp. 48-120, 1965.

Descriptors: cost of time; highway location.

This paper gives the preliminary results of a recent field study on the cost of passenger car time savings. The major objective

of the study was to determine an appropriate hours-to-dollars conversion factor for analyses and evaluation of alternative highway locations and designs. Traffic projections, economy studies, and planning reports for current and future construction projects were examined in several states. A set of procedures is also included for use by state highway departments in dealing with the cost of time. A generalized procedural checklist for highway economy studies also is included.

- 9.30 DALE, CHARLES W., and WINFREY, ROBLEY, "Applications of Highway Engineering Economy." Highway Research Circular No. 29, pp. 2-10.

Descriptor: highway engineering economy.

This discussion is primarily devoted to engineering economy, or road consequences, as contrasted to the broader social and economic consequences of highway transportation. Examples of types of improvements adaptable to an analysis for economy are listed, some of them concerned with route location, design, traffic controls, management policies, etc.... Factors necessary to a complete analysis for economy are listed also, some of them being: design factors, roadway conditions, traffic conditions, traffic classification and volume, highway costs, etc.... The authors hope that this discussion of the applications of economy analyses and the factors needed for a complete analysis will make the uninformed aware of the possibilities of the uses of engineering economy analysis and will direct the efforts of the informed to research on those factors where the data are skimpy or non-existent.

- 9.31 The Economics of National Security. YOSPHE, HARRY B., and BROWN, FRED R., "Transportation: The Nation's Lifelines." Industrial College of the Armed Forces, Aug., 1964, 152 pp. Highway Research Abstract, Vol. 35, No. 7, July, 1965, pp. 9-10.

Descriptors: transportation regulation; economics; policy.

The purpose of this new edition is to provide a general orientation in the field of transportation. The role of various modes of transportation in our economy is highlighted. The essential features and complexities of governmental organization for transportation and of national regulatory and promotional policies and programs are portrayed. Attention is also directed to the role of the government as a user and an operator of transportation.

- 9.32 "The Effect of a Bypass on Retail Trade." Washington State Highway Commission, 1965, 39 pp., Highway Research Abstracts, Vol. 36, No. 5, p. 6, May 1966.

Descriptors: economic impact; bypass.

This article discussed the effects on a town where a bypass has been placed.

- 9.33 FLAHERTY, MARK C., "Commercial Highway Service Districts and the Interstate, Their Proper Relationship in an Urban Setting," Highway Research Record No. 96, 1965, pp. 8-18.

Descriptor: land use development.

This paper discusses a method by which local officials can better guide lane-use development opportunities available as a result of Interstate Highway construction. The questions of locations near interchanges of commercial highway service districts is examined from the point of view of interchange function and design, traffic conditions, user costs and lane-use environment. Indices are suggested to guide decisions on locating service districts. A method for determining the amount of lane that should be made available in service districts for highway-oriented uses is presented. Also demonstrated are the differences in land development occurring when highway-oriented lane-use planning principles are recognized and followed or when they are ignored.

- 9.34 FRANKLAND, BAMFORD, "Land-Use Control at Freeway Interchanges in California." Traffic Quarterly, Vol. XIX, No. 4, Oct., 1965, pp. 541-555.

Descriptors: land use; interchanges; impact.

This article defines and discusses the "community," impact and the role of the freeway; discusses the essential function of land-use control in terms of community values; and analyses proposals to remove effective decision-making power from local hands. New developments in California which promise to be helpful in terms of user - benefit preservation are described and discussed.

- 9.35 FRIEDLAENDER, ANN F., "The Interstate Highway System: A Study in Public Investment." Contributions to Economic Analysis 38, North Holland Publishing Co., 178 pp., 1965. Highway Research Abstract, Vol. 35, No. 10, Oct., 1965, p. 5.

Descriptor: economic investment.

In terms of pure economic efficiency, this analysis indicates that although the construction of the rural Interstate System should not have been undertaken in its proposed form, that of urban Interstate System is probably justified.

- 9.36 GAMBLE, H. B., RAPHAEL, D. L., and SAUERLENDER, O. H., "Direct and Indirect Economic Impacts of Highway Interchange Development." Highway Research Record No. 149, 1966, pp. 42-55.

Descriptor: economic impact.

This paper deals with the type of benefit which involves the local returns or the economic impact on an area as a result of the expenditures for new highway construction and the new expenditures generated by users of the highways. The use of the input-output technique in measuring the economic impact of new highway on a region was demonstrated. The economy of a micro-region was simulated with a Leontief

Static Model. Additional sectors were added to the model to account for the new economic activities due to a new highway. Inputs consisting of new external income to the region were estimated. Impact response functions were also derived from the model.

- 9.37 GERN, R. C. and H. R. JOYNER, "Crossroute Access Design in Interchanges Areas," Highway Research Record No. 59, 1964, pp. 1-8.

Descriptors: interchange design; land use.

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 crossroute. In this research, approximately 60 of the most common and important design situations were studied in detail. For each of these 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 crossroute. 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.

- 9.38 HANING, CHARLES R., and WOOTAN, C. V., "Value of Commercial Motor Vehicle Time Saved," Highway Research Record No. 82, 1965, pp. 54-76.

Descriptors: time savings; commercial vehicle benefits.

The purpose of this paper is to explore the possibilities of determining reliable estimates of the dollar value that would accrue to commercial motor vehicle operators as a result of time savings occurring through use of improved highway facilities. Any information developed by this study will supplement the several previous studies of vehicular travel time and fuel consumption rates under various operating conditions. The main purpose of these studies has been to provide reliable information for use in determining the benefits accruing to the users of the Federal Aid Highway System.

- 9.39 HORWOOD, EDGAR M., "Community Consequences of Highway Improvement," (Abridgment) Highway Research Record No. 96, 1965, pp. 1-7.

Descriptor: impact; bypasses.

This paper discusses the effect of bypasses, urban radial and urban circumferential freeways upon communities. It was found that bypasses have differential effects on communities, with least benefit generally derived by town of less than 5,000 population and by highway-oriented businesses. Greater benefit accrued to the larger centers and to the non-highway oriented business sector; presumably due

to decreased congestion, greater pedestrian amenity in shopping areas and an enlarged shopping area. Small towns without central place importance may suffer substantially from a highway bypass.

- 9.40 JOHNSON, BRUCE M., "On the Economics of Road Congestion," *Econometrica* Vol. 32, No. 1-2, pp. 137-150, April, 1964, Highway Research Abstracts, Vol. 34, No. 19, p. 3, Oct., 1964.

Descriptors: model; traffic congestion; economics; tax schedules.

This paper presents a model in which the market demand for urban automobile travel is a function of a time-price as well as a money-price and the market supply is represented by a flow function that is derived from assumed relationships between traffic density and average speed. Two qualitatively different types of traffic congestion are identified. Marginal cost pricing in terms of both time and money taxes is proposed as an efficient and feasible means of controlling both types of traffic congestion. Using the results of existing empirical studies, tax schedules for three types of urban roads are computed.

- 9.41 JOHNSON, W. F., "Use of Traffic Volume Data in Evaluation of Highway-User Costs for Economic Analysis," Highway Research Record No. 100, 1965, pp. 38-46.

Descriptor: user costs.

The unit cost of highway travel per vehicle-mile is a function of many variables such as vehicle type, geometric design, road surface, and traffic density. This paper describes a technique which accounts for the variation in traffic volume over time for computation. The variation in traffic volume per hour over a year is reduced to a frequency distribution of hourly volumes. A volume-speed characteristic relating average travel speed to volume of traffic in vehicles per hour is used as a basis for a volume-unit cost relationship. The application of the technique to compute annual user costs on different highways is discussed. The volume-cost function is developed from basic traffic flow principles and is related to driver characteristics, vehicle characteristics, and highway characteristics. Computer programs have been developed to process data and perform calculations.

- 9.42 JUHL, H. G., "Losses from Traffic Tie-Ups - Their Estimate and Solution," *Better Roads*, Vol. 34, No. 10, Oct., 1964, p. 23-5.

Descriptors: cost of time loss; total waiting time.

Simple method is developed to determine total waiting time of all motor vehicles involved in line-up for cases where length of line-up, its duration and capacity of bottle-neck are known; formulas for determining cost of time loss caused by line-ups.

- 9.43 KULICK, MATTHEW J., "Financing the Maintenance of the National System of Interstate and Defense Highways." University of Rhode Island, "Bureau of Govt. Res." Res. Series No. 7, 1964, 40 pp. Highway Research Abstract, Vol. 35, No. 4, April, 1965, p. 7.

Descriptors: cost; maintenance; financing.

There is considerable evidence in this study to support the contention that the states will not be able, by themselves, to bear the burden of maintaining the Interstate Highway System and that the Federal Government should revise its laws to assist the states in maintenance of the Interstate System.

- 9.44 "Law of Turnpikes and Toll Bridges: An Analysis Appendix C - Selected Bibliography of Writings on Turnpikes and Toll Bridges." Highway Research Board Special Report 83, pp. 115-117, 1964.

Descriptors: turnpikes; toll bridges; bibliography.

This appendix presents a list of 52 books and periodicals and eight legislative hearings and reports on turnpikes and toll bridges.

- 9.45 MARKS, HAROLD, and SPIETZ, SALEM, "A Review of Transportation Aspects of Land-Use Control." NCHRP Report, 1966, 41 pp.

Descriptors: traffic control; design; land-use control.

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.

- 9.46 MCKAIN, WALTER C., "Community Response to Highway Improvement," Highway Research Record No. 96, 1965, pp. 19-23.

Descriptor: economic development.

This article concurs that highway improvements may furnish the external stimulus essential for economic development in an area but the immediacy of the response and the extent of economic growth depend on the capacity for change existing within the community. The Connecticut Turnpike had a favorable impact on the economic development of some towns in eastern Connecticut, whereas others were left

relatively untouched. An attempt is made to illustrate the influence of human factors and social conditions on economic development with particular reference to the effect of a textile mill economy.

- 9.47 MOHRING, HERBERT, "Relation Between Optimum Congestion Tolls and Present Highway User Charges." Highway Research Record No. 47, 1964, pp. 1-14.

Descriptor: toll structure.

The main purposes of this paper are to develop some rough estimates of the optimum congestion toll structure for a large urban center and to provide some even rougher estimates of the costs that result from the inability and/or unwillingness to impose such tolls.

- 9.48 NETHERTON, ROSS, and MARKHAM, MARION, "Condemnation of Land Adjacent to Interchanges: A Test of the Special Benefit Concept." Highway Research News 16, pp. 11-19, Dec., 1964.

Descriptor: right-of-way.

This paper reports on two right-of-way cases recently decided by the Vermont Supreme Court. In both cases - *Hove v State Highway Board*, 187 A. 2d 410 (Oct. 1963) condemnation of land by the State for Interstate System right-of-way resulted in partial takings and the award of severance damages. The condemnor sought to reduce these damages by questioning whether construction of an expressway interchange near to but not abutting the severed remainder may be recognized as conferring a special benefit on the remainder.

- 9.49 PENDLETON, WILLIAM C., "An Empirical Study of Changes in Land Use at Freeway Interchanges." Traffic Quarterly, Vol. XIX, No. 1, January, 1965, pp. 89-100.

Descriptors: photogrammetry; land use; interchanges.

This paper discusses the use of aerial photographs, in assembling data on changes in land use, and presents the findings from a study of land development around sixty-four freeway interchanges. The data are also used to illustrate and test a simple model incorporating variables expected to be useful in explaining observed rates of change.

- 9.50 PHILLSBURY, WARREN A., "Economics of Highway Location: A Critique of Collateral Effect Analysis." Highway Research Record No. 75, 1965, pp. 53-61.

Descriptor: economics of highway location.

This paper reviews highway location methodology in general and discusses collateral effect analysis from the point of view of the marginal theorists.

- 9.51 NEWCOMB, ROBINSON, "New Approach to Benefit-Cost Analysis." Highway Research Record No. 138, 1966, pp. 18-21

Descriptor: benefit-cost analysis.

This paper is a short challenge to the basic premise frequently used that if each of two proposed roads will provide the same capacity, but one will yield greater cost reduction than the other, the road which will yield greater savings in transport cost should be selected. It is the thesis of this brief paper that this conclusion may be false. The solution which requires the least total social costs for the benefits provided, is the solution to seek. If this solution does require a greater transport investment than some other solutions, but will decrease other costs more than it increases transport costs, it will benefit the community more than a solution with lower transport but higher other costs.

- 9.52 SAWHILL, ROY B. and CRANDALL, KEITH C., "Some Measurable Qualities of Traffic Service Influenced by Freeways." Highway Research Record No. 49, 1964, pp. 30-63.

Descriptors: traffic service - travel time; fuel consumption.

Data is evaluated on travel time and fuel consumption. Traffic volume relief is presented for one study area to reflect non-user benefits in the form of accessibility and also to present an insight into significant changes in travel time and fuel consumption.

The first portion of the report presents the characteristics of benefits in the form of travel time, overall speed, delay, fuel consumption, distance, and volume for freeway bypass routes as compared to the older business routes.

The rest of the report analyzes the effect on travel time and fuel consumption of speed of operation and traffic volume. The economics of movement of vehicles at various speeds is also investigated to establish the most efficient speed on the basis of values of travel time and fuel.

- 9.53 SAWHILL, ROY B., "Freeways and Residential Neighborhoods." (Abridgment) Highway Research Record No. 149, 1966, p. 57.

Descriptors: benefits; land use; accident hazards.

The purpose of this study is to evaluate the influence freeways have when they traverse rather than circumscribe a neighborhood area. The method of making the evaluation was by the collection of data relative to land use, household characteristics, traffic volumes and accident hazards. It is difficult to determine whether or not the new area opened to the North Broadway residents of Seattle, Washington will be better or worse for North Broadway than the present trend now dividing the area. However, the decrease in volumes and accidents was a definite boon to the area.

- 9.54 CHALLER, LYLE E., "How Free are Freeways?" Municipal Signal Engineer, Vol. 30, No. 6, pp. 25-29, Nov.-Dec. Hwy Research Abstract, Vol. 36, No. 6, p. 4, June, 1966.

Descriptor: cost.

The article discusses the cost of freeways.

- 9.55 "Severance Study Proves Valuable Tool for Use in Modern Highway Building." Highway Traffic, Vol. 18, No. 4, p. 8, Oct., 1963, Highway Research Abstracts, Vol. 34, No. 2, pp. 5-6, Feb., 1964.

Descriptors: severance; land use.

This paper discusses a severance study made along Interstate 64 in Kentucky. In general, the use of the lane remained the same.

- 9.56 SHELDON, WILLIAM P. and STRAUB, ARTHUR L., "A Digital Computer Technique for Calculating Cost of Right-of-Way." Highway Research Record No. 54, 1964, pp. 101-110.

Descriptor: right-of-way costs - computer calculations.

This article describes a digital computer program for making a land cost analysis along a highway right-of-way. The principle employed for determining a "running" (per station) cost along the center line projection is basically one of matrix theory. Essentially, two matrices exist within the system; one used to define the location of the route centerline is superimposed on another used to assign varying costs to pieces of land in the area. Following development of the programming written in FORTRAN coding, an analysis was conducted on five hypothetical lines. Limitations of the approach and possible applications are discussed.

- 9.57 THIEL, FLOYD L., "Interchange Area Development", Highway Research Record No. 96, 1965, pp. 24-45.

Descriptor: interchange area development - control.

This paper discusses how interchange research accomplished or sponsored by State highway and planning agencies has provided tentative findings on several aspects of the interchange problem. For example, some combination of lane-use controls involving both the police power and eminent domain appears to be needed to guide interchange development in most areas. Local initiative should be relied on to the greatest extent possible, though State action will no doubt be needed in some instances. Guidance for development in interchange areas can also be encouraged by State highway agencies and others making available to local planning authorities those facts needed to act in local interchange planning situations.

- 9.58 THIEL, FLOYD L., "Some General Findings from Severance Studies." Presented to the 51st Annual Purdue Road School, March 29-April 1, 1965. Engineering Extension Series, No. 119, pp. 69-84.

Descriptor: severance.

This paper presents a study of severance cases. Recovery rates, damage estimates, landlocked parcels, time of sale, interchange effects, type of highway system, and damages are considered. The material is presented in statistical form.

- 9.59 THOMPSON, R. H. and ADKINS, W. G., "Some Economic Effects of the Suburban Portion of North Central Expressway, Dallas, Texas." TTI Bulletin No. 15, June, 1961, 26 pp.

Descriptors: land use; economic impact.

This report presents the findings of a study of the impact of a suburban radial freeway upon the value and use of adjacent land and upon the size and character of a small town whose accessibility to the Central Business District of Dallas it greatly improved. Land values were based on a "before" period of 1946 to 1951 and an "after" period of A52 to A60. To account for changes due to factors other than the freeway, control area and control towns removed from the freeway were also considered.

Results of this study indicated a marked increase in value of land adjacent to the facility. In terms of constant dollars, the value of unimproved, abutting land was increased 260 percent. Where the freeway traversed open land, development occurred slowly during the "after" period, but very little development occurred in the control area.

Travel time between Dallas and Richardson, the town under consideration, was reduced from 30 to 17 minutes. Population increased at a generally higher rate than for the control towns (from 2,890 in 1955 to 16,810 in 1960). Other comparisons with the control towns indicated that Richardson received important benefits from its location on the North Central Expressway.

- 9.60 TREADWAY, T. B., and OPPENLANDER, J. C., "An Analysis of the Travel Conditions on the U. S. 52 Bypass in Lafayette, Indiana." Presented to the 51st Annual Purdue Road School, March 29-April 1, 1965. Engineering Extension Series, No. 119, pp. 200-207.

Descriptors: traffic service; traffic flow; research techniques; bypass.

This paper reports on a study whose specific objectives were:

1. To determine the significant variables which influence travel speeds and delays;
2. To develop equations using these significant variables to predict travel speeds and delays; and
3. To make recommendations of traffic engineering techniques to improve the movement of traffic on this bypass facility.

Procedure of the research is presented.

- 9.61 WINKLEMAN, DON and SCHWINDEN, JAMES, "Benefits and Costs of Modification to Interstate Highways," Univ. of Minnesota for Minnesota Highway Dept., Sept., 1963. Highway Research Abstracts, Vol. 34, No. 11, p. 20, Nov., 1964.

Descriptors: maintenance; benefit-cost.

This report examines some of the criteria that might be employed in decision problems and roads for choosing among requests for services.

- 9.62 WOHL, MARTIN, "Costs of Urban Transport Systems of Varying Capacity and Service." Highway Research Record No. 64, 1965, pp. 1-70.

Descriptors: cost analyses; modes of transport.

This report defines a framework for properly conducting cost analyses and utilizing the results for decision making, and roughs of "cost boundaries" for evaluating present-day technologies by establishing, on an analytical basis, the situations and conditions under which particular forms of transport offer cost or service economies.

- 9.63 WOHL, MARTIN, "The Short-Run Congestion Cost and Pricing Dilemma," Traffic Quarterly, Vol. 20, No. 1, pp. 48-70, Jan., 1966, Highway Res. Abstracts, Vol. 36, No. 8, p. 3, August, 1966.

Descriptors: travel costs; pricing.

This paper is concerned solely with short-run travel costs and effects, and only treats the circumstances of costing and pricing the usage of existing highways of fixed capacity in the short run.

- 9.64 WOLFE, R. I., "Effect of Ribbon Development on Traffic Flow." Traffic Quarterly, Vol. XVIII, No. 1, 1964, pp. 105-117.

Descriptors: traffic flow; ribbon development.

This paper discusses the effect of ribbon development on an area's ability to serve the traffic.

- 9.65 WOOLAN, C. V., MEUTH, H. G., "Changes in Land Value, Land Use and Business Activity Along a Section of the Interstate Highway System in Temple, Texas," TTI Bulletin No. 14, Sept., 1960, pp. 1-33.

Descriptors: land values; land use; economic development.

This report is based on the results of the second in a series of studies designed to measure and analyze the effects that the construction of sections of the interstate system has on local areas: The influences discussed were caused by the construction of a new bypass route for U. S. 81 (Interstate 35) around Temple, Texas.

- 9.66 WOOLAN, C. V., MEUTH, H. G., ROWAN, N. J., WILLIAMS, T. G., "A Median Study in Baytown, Texas." TTI Research Report 8-1, Bulletin No. 29, Aug., 1964, pp. 7-32.

Descriptors: medians; economic analysis; accidents.

This article reports on the "before" and "after" travel and economy on a Baytown arterial before and after medians were employed. Results were generally favorable.

C. COMMERCIAL VEHICLES AND TRUCK-LANES

- 9.67 HODGKINS, EDMUND A., "Effect of Buses on Freeway Capacity." Highway Research Record No. 59, 1964, pp. 66-82.

Descriptors: capacity; bus lanes.

This paper reports on a study to measure the speeds and the spacing between buses on freeways and to determine the passenger car equivalent of buses on such roads, thus permitting determination of the theoretical capacity of the separate all-bus lane on a freeway. It was felt that by studying a combination of speed-volume data and "cluster" data, it would be possible to develop capacity values as well as to determine the effect of buses on the traffic stream. Conclusions are reached as to when it would be desirable to designate separate lanes as bus lanes.

- 9.68 NEWMAN, LEONARD, and MOSKOWITZ, KARL, "Effect of Grades on Service Volume." Highway Research Record No. 99, 1965, pp. 224-243.

Descriptors: trucks, capacity.

The problem of determining effects of trucks or any slow-moving vehicles on the operating characteristics of a section of multilane road is discussed. The action of trucks in reducing the service volume of a road is described and is related to the number of trucks, speed of trucks (steepness of grade), and length of grade. Relationship between these factors are developed and presented in the form of a proposed design chart for determining equal service volumes which would be suitable for rural conditions for any combination of grade, autos, and trucks. The use of this chart in determining when additional lanes should be added and the effects of trucks on maximum capacity of a road are described.

- 9.69 "Traffic Surveys", The Engineering Index, Oct., 1966, p. 266.

Descriptors: simulation; signalization; streetcars.

Computer simulation on traffic flow at street intersection; N. Yomoto, T. Fiyimoto, A. Ohashi, S. Yamasaki. Sumitomo Elec. Tech. Review, N. 7, Feb., 1966, p. 58-61. Computer simulation was made of traffic flow at intersection where street cars as well as vehicles were signal controlled by traffic-actuated local controller; street surface was divided into small portions, each identified by location, with data on presence of vehicles, streetcars, and pedestrians, including their arrival time; they were moved step by step according to set rules vehicle passage time was found to be reduced by half by actuation method; motion pictures were taken of results of simulation by spotting vehicles on oscilloscope

screen.

D. MAINTENANCE AND OTHER OPERATIONAL PROBLEMS

- 9.70 "Airfield Type Sweeper is a Natural for California Freeways," Public Works, Vol. 97, No. 1, p. 93, Jan., 1966. Hwy. Res. Abstracts Vol. 36, No. 8, p. 13, August, 1966.

Descriptor: maintenance - freeway cleaning.

This report discusses the use of an oversized air jet vacuum cleaner to clean the freeways in California.

- 9.71 BRASCH, JEROME K., "Vehicular-Traffic Noise Near High-Speed Highways," Journal of the Acoustical Society of America, Vol. 37, No. 6, pp. 1197-1198, June, 1965, Hwy. Res. Abstracts Vol. 36, No. 3, p. 7, March, 1966.

Descriptor: highway noise.

This is a study of high-speed highway noise where the loudness and level have been calculated according to the methods of S. S. Stevens.

- 9.72 BROHM, D. R., COOKE, W. G., and LESLIE, A., "Snow and Ice Control on the Provincial Highway System of Ontario", Ontario Dept. of Highways, Materials and Research Division Report No. 45, 1964, Highway Research Abstracts, Vol. 34, No. 11, p. 14, Nov., 1964.

Descriptors: winter maintenance, design features.

This paper describes the winter maintenance administration, operations and equipment of the Ontario Dept. of Highways.

Factors determining the standard of service provided are reviewed and design features affecting winter maintenance are enumerated.

The need for prompt remedial action is stressed and the value of two-way radio communication is emphasized. Examples are given of typical action taken under various storm conditions

Specifications for abrasives and chemicals for winter use are provided and details of the standard items of snow-clearing equipment are given.

Safety and developments in equipment in Ontario are discussed briefly.

- 9.73 CRITTENDEN, BRADFORD M., "Policing Controlled Access Highways", Traffic Engineering, Vol. 34, No. 5, Feb., 1964, pp. 11-13.

Descriptors: freeways; law enforcement.

This paper gives a most vivid description of the policing problems on freeways. It is a problem which should be the concern of not only the police, but of the engineers and motor vehicle administrators as well.

- 9.74 DICK-FEDDIE, W. A., CAMPBELL, C. J., "Roadside Development", New Mexico State University, Engineering Experiment Station Bul. 31, July, 1965, 53 pp. Highway Research Abstracts, Vol. 36, No. 5, pp. 10-11, May, 1966.

Descriptor: erosion control.

Tells of a four-year study on erosion control by vegetation along southern New Mexico highways.

- 9.75 GOODWIN, CHARLES A., "It Pays to Minimize Traffic Hazards During Road Construction," Public Works, Vol. 94, No. 10, pp. 126-128, 200-204, Oct., 1963. Highway Research Abstract Vol. 34, No. 9, pp. 13-14, Sept., 1964.

Descriptor: traffic control during road construction.

This is a discussion of the basic principles involved in the control and protection of traffic and pedestrians moving through, across and around construction projects. The standards and procedures recommended in this text are based on widely accepted practices for public safety. Traffic control devices, and their proper application, sign types, and highly visible barricades are discussed as good methods of preventing accidents dealing with construction projects.

- 9.76 KLUCHER, R. H., "Maintenance Experience on the Pennsylvania Turnpike." Presented to the 51st Annual Purdue Road School, March 29-April 1, 1965. Printed in the Engineering Extension, No. 119, pp. 28-41.

Descriptors: maintenance, costs.

This article discusses maintenance projects on the Pennsylvania Turnpike. Resurfacing, bridge deck maintenance, the addition of two lane tunnels, and maintenance costs are considered.

- 9.77 LEDBETTER, W. B., "Correlation Studies of Fundamental Aggregate Properties with Freeze-Thaw Durability of Structural Lightweight Concrete." TTI Research Report 81-1, Aug., 1965, pp. 5-14.

Descriptors: synthetic aggregates; durability.

This study investigates the relationship between selected fundamental synthetic aggregate properties and freeze-thaw durability of lightweight concrete made with these aggregates. Five light weight coarse aggregates and regular weight coarse aggregate were selected for study. The objective was to determine the effect of coarse aggregate type and cement factor on concrete freeze-thaw durability. Wide differences were found in the engineering properties of the 5 lightweight aggregates. No correlation was apparent between any of the aggregate properties determined and concrete durability. When samples were subjected to severe freeze-thaw tests, it was found that the durability of non-air entrained concrete is influenced greatly by the type of coarse aggregate used and to a lesser degree by the cement factor. Tentative observations indicate the possibility of some correlation between aggregate freeze-thaw durability and concrete freeze-thaw durability.

- 9.78 SCHAEERER, P.A., "Melting Snow and Ice by Heating Pavements", Building Research Note No. 5, National Research Council, Division of Building Research., Canada, Jan., 1966, 12 pp. Highway Research Abstracts, Vol. 36, No. 8, pp. 12-13. August, 1966.

Descriptors: maintenance; snow and ice removal - costs, benefits.

This paper discusses the use of heat to melt snow and ice on our highways and freeways; the benefits and costs.

- 9.79 SKORIK, I. I., "Utilization of Certain Substances for the Acceleration of the Melting of Ice." Trudy Arktichesko-Kogo I Antarktichesko-Kogo Nauchno Issledovatel'skogo Intituta, 218:200-208, 1960, Highway Research Abstracts, Vol. 34, No. 5, pp. 5-6, May, 1964.

Descriptors: maintenance; ice removal.

This translation describes results obtained from a Russian study on the effectiveness of various dusting materials for advancing the break-up of an ice cover. Conclusions reached indicate that dusting ice surface with hard insoluble finely-dispersed materials promotes the thawing and destruction of the ice cover and depends on the nature and degree of subdivision of the dispersed material as well as on the density of dusting of the ice surface with this substance. Sand and coal dust are considered, as are the effects of dyeing the sand with Prussian blue and aniline black.

- 9.80 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.

Descriptors: traffic noise - control; land area control, distance.

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.

- 9.81 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.

Descriptors: access control violations - types; causes, control.

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 effectiveness ratios.

- 9.82 TOWNE, ROBIN M. AND ASSOCIATES, and STEEL, DAVID C., "Noise in Hospitals Located Near Freeways." Available from: Clearinghouse, Springfield, Virginia. PB 177379 and PB 177380. 1964, 2 vols.

Descriptors: freeway noise; hospitals.

A detailed study made of noise environment inside and outside of hospitals.

- 9.83 WOOTAN, C. V., MEUTH, H. G., ROWAN, N. J., WILLIAMS, T. G., "A Median Study in Baytown, Texas." TTI Research Report 8-1, Bulletin No. 29, August, 1964, pp. 7-32.

Descriptors: medians; economic analysis; accidents.

This article reports on the "before" and "after" travel and economy on a Baytown, Texas, arterial before and after medians were employed. Results were generally favorable.

E. MOTORISTS AND MOTORIST SERVICES

- 9.84 "Two New Aids for Expressway Drivers." Cook County Highways, Vol. 12, No. 12, p. 2, May, 1965. Highway Research Abstract, Vol. 35, No. 11, Nov., 1965, p. 8.

Descriptors: driver location; location markers.

The Illinois Division of Highways will erect a system of location identification markers to enable a stranded driver to report exactly his location. Motorists who equip their cars with instruments operating on a special wave band voluntarily report traffic troubles they may witness as well as calls for help for themselves. Location markers will be mounted on street light poles and freeway ramps will also be marked.

- 9.85 COVAULT, DONALD O., and BOWES, ROBERT W., "A Study of the Feasibility of Using Roadside Radio Communications for Traffic Control and Driver Information." Highway Research Record No. 49, 1964, pp. 89-106.

Descriptors: communications; radios; traffic control; driver information.

This paper discusses a new radio system tested in July 1963 on the Kentucky Turnpike. A random sample of vehicles were selected, one-half as a test group, and one-half as a control group. Experiments involved accident scenes, typical maintenance activities, and route information. Results of the experiments showed that this is an effective device in controlling

vehicle speed in hazardous areas, as witnessed by the significant speed differences of the test and control vehicles at the hazardous locations.

- 9.86 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.

Descriptors: traffic control; radio communication; driver information.

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.

- 9.87 DEAKIN, OLIVER A., "Planting for Screening Headlight Glare and Traffic Guidance." Highway Research Record No. 53, 1964, pp. 17-25.

Descriptors: roadside planting; headlight glare; driver guidance.

This is a supplemental report on "Planting for Screening Headlight Glare and Traffic Guidance" to record and show what progress has been made in the use of various species of plant materials for special problems. This record of information as of 1963, is to supplement information already published by the Highway Research Board (1, 2, 3). The Committee is interested in the functional use of plant materials along road-sides for the purpose of making the highways safer to drive, more attractive and pleasant to travel, and less costly to maintain.

- 9.88 FONDA, ROY D., and ATHOL, PATRICK J., "Motorist Aid Phone Study." Traffic Engineering, Vol. 37, No. 7, April, 1967, pp. 26-32.

Descriptor: motorist aid phone.

This article is about a communication system on freeways.

- 9.89 GILBERT, RICHARD H., "Helicopter Traffic Reports in Chicago, Illinois." Traffic Quarterly, Vol. XIX, No. 4, Oct., 1965, pp. 537-577.

Descriptors: driver information, helicopter traffic reporting.

This article discusses radio broadcasts of current traffic conditions as viewed from a helicopter.

- 9.90 HILL, G. A., "Safety Roadside Rests", Calif. Highways and Public Works, Vol. 44, Nos. 7-8, pp. 8-10, July-Aug., 1965, Hwy. Research Abstract, Vol. 36, No. 3, March, 1966, p. 4.

Descriptor: roadside rest areas.

In this study, it tells the modernization of roadside parks on heavily traveled highways.

- 9.91 KELCEY, GUY and HALSTEAD, WILLIAM S., "Multi-Purpose Highway Communications by Induction Radio." Surveyor and Municipal Engineer, Vol. 125, No. 3811, pp. 63-64, June 19, 1965, Highway Research Abstract, Vol. 35, No. 11, Nov., 1965, pp. 9-10.

Descriptors: communications; induction radios.

This paper discusses the use of vehicle-carried induction-radio-telephone equipment or interconnection with conventional two-way systems that will enable communication with roadside control points or police stations in event of a breakdown, accident or other difficulty. This type of equipment can be installed at low cost, and prove advantageous over other methods because of its location, and its accessibility for maintenance and servicing.

- 9.92 SALVATORE, SANTO, "Estimation of Vehicular Velocity Under Time Limitation and Restricted Conditions of Observation." Presented as a paper to the 46th Annual Meeting of the Highway Research Board, Jan. 16-20, 1967, Hwy. Research Record No. 195, 1967, pp. 66-74.

Descriptor: motorist - estimation of velocity.

This study reports an investigation of the ability of subjects to estimate the velocity of their vehicles.

- 9.93 SENDERS, J. W., KRISTOFFERSON, A. B., LEVISON, W., DIETRICH, C., and WARD, J., "The Attentional Demand of Automobile Driving." Highway Research Record No. 195, 1967, pp. 15-33.

Descriptor: driver behavior model - information processing.

This paper reports on a study made of drivers' habits in watching the road. The analysis makes specific predictions about the form of the functional relationship between intervals between observations and vehicle speed. The program had two goals: (1) the empirical investigation of the relation between amount of interruption of vision and driving speed; (2) the determination for various drivers and various roads of the values of some of the parameters in the mathematical model. The model is thought to be a fair approximation of actual behavior.

- 9.94 STEPHENS, BURTON W. and MICHAELS, R. M., "Time Sharing Between Compensatory Tracking and Search-and-Recognition Tasks." Highway Research Record No. 55, 1964, pp. 1-16.

Descriptors: driver behavior; task recognition.

This study deals with one aspect of driving behavior; i.e., the sharing of time between two types of activities that the driver is forced to accept as a part of the driving task. Steering and the recognition behavior has been abstracted and explored in the laboratory by analyzing performance on a compensatory tracking task taken as an analog of steering and on filmed presentation of a sign search-and-recognition task. The relative effects of the interaction between tasks were explored. The main findings of the study were that (a) where time sharing was required, each type of performance was degraded; (b) increasing the number of message units appearing in the recognition task did not differentially affect simulated steering performance but did increase the time required for recognition of a key message; (c) increased speed of the simulated steering task displayed decreased recognition time of the discrete visual task; and (d) where a specific message had equal likelihood of appearing or not appearing, recognition time was greater when the key word did not appear. Results are discussed in terms of operator sampling behavior.

- 9.95 WAGNER, LOUIS C., and HARDER, VIRGIL E., "Methods of Providing Information to Motorists on the Interstate System." Traffic Quarterly, Vol. XIX, No. 4, Oct., 1965, pp. 504-519.

Descriptor: driver information.

This article sets forth two constraints which surround the interstate system and which therefore require a change in the concept of how information will be provided to motorists. A second section discusses the existing means which are used to provide information. A third section discusses potential means which may be used. Safety rest areas with information displays suggested as the best means of communications.

- 9.96 WEINBERG, MORTON I., DELEYS, NORMAN J., and SCHNEEBERGER, RICHARD F., "Surveillance Methods and Ways and Means of Communicating with Drivers", NCHRP Report No. 28, Project 3-2, pp. 1-66.

Descriptors: driver communications; surveillance methods.

This study is concerned with researches on traffic surveillance systems for urban freeways. Investigations have been performed on (a) a method for predicting travel time on an urban freeway in the event of a traffic tie-up, and (b) the effectiveness of an airborne observer to reroute traffic in the event of traffic tie-up. The object of this research was to devise, for the John C. Lodge Freeway in Detroit, an "early warning" system that could provide information on which to base advisories to motorists to avoid the freeway

and seek alternate routes.

- 9.97 WEINBERG, MORTON I., "Traffic Surveillance and Means of Communicating with Drivers: Interim Report." NCHRP Report 9, 1964, 28 pp.

Descriptors: surveillance methods; driver communications.

This study is concerned with the development of a specification for a traffic control system for urban freeways. The specific problems investigated are (a) methods of predicting congestion, (b) the effectiveness of an airborne observer, and (c) the design of a ramp access advisory signal. The first section describes an attempt to formulate a mathematical model on which a method of anticipating traffic congestion can be based.

- 9.98 "Two-Way Radios Send H.E.L.P. to Motorists in Distress." Traffic Safety, Vol. 65, No. 4, pp. 11, 35, April, 1965. Highway Research Abstract, Vol. 35, No. 9, Sept., 1965, pp. 8-9.

Descriptor: driver communications - radios.

The system, to be known as H. E. L. P. (Highway Emergency Locating Plan), calls for the use of Citizens Band two-way radio equipment in private passenger cars. Announcement of the new plan was made by the Automobile Manufacturers Association, which pointed out that more than 2 million pieces of CB equipment are already in use. CB equipment also can be used by motorists for their business or personal communications.

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