Operation and Maintenance of Transportation Facilities:

STATEMENTS OF RESEARCH PROBLEMS

TRB

SPECIAL REPORT 158
Transportation Research Board
National Research Council

1975 TRANSPORTATION RESEARCH BOARD

The identification of research problem areas is one of the important functions of the Transportation Research Board's technical committees. When research problem statements are developed and disseminated to transportation organizations and research agencies, it is frequently difficult to determine what action results. The Group 3 Council is eager to know how the research problem statements in this report are used. If your organization takes action on any of the problem statements, please take a few minutes to report it on one of the attached return cards.

GROUP 3 RESEARCH PROBLEM STATEMENTS

The following problem statements resulted in action by our organization:

1.

2.

3.

Briefly describe research efforts.

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Name _____

Organization _____

Address _____

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subject areas
22 highway design
24 roadside development
40 general maintenance
41 construction and maintenance equipment
51 highway safety
52 road user characteristics
53 traffic control and operations
54 traffic flow
55 traffic measurements

The conference that is the subject of this report was approved by the Governing Board of the National Research Council acting in behalf of the National Academy of Sciences. Such approval reflects the Governing Board's judgment that the conference is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the committee selected to organize the conference and to supervise the preparation of this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project.

Responsibility for the selection of the participants in the conference and for any summaries or recommendations in this report rests with that committee. The views expressed in individual papers and attributed to the authors of those papers are those of the authors and do not necessarily reflect the view of the committee, the Transportation Research Board, the National Academy of Sciences, or the sponsors of the project.

Each report issuing from such a conference of the National Research Council is reviewed by an independent group of qualified individuals according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved by the President of the Academy upon satisfactory completion of the review process.

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Contents

Statements listed in priority order.

Introduction

L. G. Byrd, Byrd, Tallamy, McDonald, and Lewis, chairman, Group 3 Council

The identification and the definition of research problems have been important and demanding activities of most of the Group 3 committees for many years. The method of publication and the use of these problem statements, however, have had considerable discussion in both committee and Group 3 Council deliberations.

The Group 3 Council recently completed a review and study of the use of research problem statements. The study resulted in a number of recommendations to strengthen the procedures for preparation, publication, and dissemination of research problem statements. Out of the study came the plan to collect and assemble these statements as a full effort of the Group 3 Council and its committees and to disseminate them in a single special publication. This Special Report is the first product of that effort. It contains 193 research problem statements that were contributed by 24 committees representing all of the 6 sections of Group 3.

The Group 3 Council gave much consideration to the questions of priorities and rankings of problem statements. Although there were and are advocates for including priority ratings with the statements, the council elected to forego any priority assignments but invited committees to include relative priorities among the problem statements they submitted, if they wished to do so. The statements under each subject area are sequentially numbered; an asterisk indicates that the listing is by priority order.

This report of problem statements does not and is not intended to represent a research "program." Instead, it is intended to offer concise, specific statements of research needs from which elements for a research program or individual projects may be drawn. It is intended to serve as a useful tool for transportation agencies, universities, foundations, and private research organizations and individuals seeking ideas, guidance, confirmation, or clarification in research activities in the transportation field.

The Group 3 Council and committees are, of course, interested in how useful these statements are to research organizations. Organizations that undertake research projects based on any of these statements are requested and urged to report briefly on the scope and results of the research either on one of the cards included with this report or by letter addressed to Group 3 Council Secretary, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

Communications*

1 Development and Management of a Highway Electronics System

Problem Statement

The annual toll of death and injuries resulting from highway accidents represents a serious waste of national resources. An effective communication system is the vital link between the public and the many agencies responsible for providing prompt emergency aid and services to highway users. A number of federal and state agencies have legislative authority or program responsibility and substantial resources for highway services and communication systems. In addition, many agencies have rural area communication needs that could be substantially met by a communication system primarily designed to serve motorists. Both the service and the cost of providing the service can be improved by coordinated management and financing.

Proposed Research

1. Analyze the current legislative assignment and responsibility of the numerous state and federal agencies for highway motorist-aid communication systems, including physical facilities, equipment, operation, and personnel training.
2. Recommend ways in which separate agency resources can be coordinated to increase efficiency and effectiveness in the delivery of emergency aid and information to motorists.
3. Establish and field test a system for multiagency coordination in the operation, management, and financing of a highway communication system.
4. Recommend policies, procedures, and programs to improve management, information exchange, planning, and coordination of activities related to highway services telecommunications among state and federal agencies.

2 Forecast of Communication Needs for Analysis of Transportation Spectrum Requirements for Land Transportation Systems

Problem Statement

The safety and efficiency of land transportation systems depend heavily on rapid and reliable communications, much of which employs radio. During a world radio conference in 1979, frequency allocations, regulations, resolutions, and recommendations governing the use of radio until the year 2000 will be adopted. The United States will develop its position for this conference by soliciting the views of all interested parties. Because of the importance of radio to the continued progress in land transportation systems, both private and government sectors of the land transportation industry must be sure that their needs are represented in the U.S. position.

Proposed Research

1. Identify all present and future land transportation system communication needs, including radar and radiolocation, and specifically those in which radio can be employed.
2. Evaluate the relative merit of the use of radio and alternatives for serving these communication needs and the technical and economic feasibility of using radio.
3. For those needs that can be met only by radio or technically or economically better by radio, develop a forecast of the number of units required and the radio spec-

trum required to implement the various systems and evaluate the feasibility of geographical and time sharing of frequencies.

4. Develop a forecast to the year 2000 of the number and growth rate of each of the radio systems.

5. For each type of radio system, recommend frequency allocations, channel bandwidths, emission limitations, and related technical and regulatory rules and recommend a study program if standards do not exist but are needed.

6. Study the probable impact of technology on the forecast needs (i.e., data versus voice transmission, computer dispatching, and automatic vehicle location).

3 Prototype Two-Way In-Vehicular Transceiver for Motorist Aid Communications

Problem Statement

Motorist aid communication systems provide a means for detecting stranded motorists so that the appropriate assistance can be given by the responding agency. Roadside electronic devices, which are used in these systems, include telephones, call boxes, and cooperative reporting systems. Roadside call boxes and telephones constitute the major means now available to stranded or disabled motorists to request aid. These devices are usually spaced from ¼ to 1 mile apart along the highway. To use these devices, motorists must usually leave their vehicles and walk along a high-speed highway. They would be much safer if they could request aid from within their vehicles. In addition, if their vehicles were suitably equipped, passing motorists could report disabled vehicles without having to stop their own vehicles. Because the in-vehicle equipment would have infrequent use, the cost should be low enough to permit purchase by a large number of users.

Proposed Research

1. Establish system and device specifications consistent with a low-cost in-vehicular unit.

2. Fabricate and test in the laboratory and field a prototype unit with a companion roadside terminal.

3. Analyze test results to determine whether units meet or exceed system specifications.

4. Estimate cost of in-vehicular units based on their being manufactured in large quantities.

4 Spectrum Requirements, Choice, and Availability for a 2-Way Motorist Aid Communication System

Problem Statement

Highway travel can be safer and more efficient if accidents, roadway conditions, traffic, and vehicle problems can be communicated to a central traffic surveillance and control center. Two-way radio provides a system with maximum coverage and minimum time lag. A major problem is the identification and selection of the most effective frequency spectrum for this purpose.

Proposed Research

1. Analyze the number of incidents in urban and interurban areas to determine the link-loading requirements for the communication system.
2. Determine spectrum requirements based on the link-loading requirements.
3. Investigate available and projected radio bands for 2-way motorist aid communication systems.
4. Develop recommendation for radio spectrum allocation for 2-way motorist aid communication system suitable for consideration by the Federal Communications Commission.

5 Audio Signing (Highway Advisory Radio) in or Near the FM Band Versus the AM Band

Problem Statement

A research and development program is being conducted by the Federal Highway Administration to develop a highway advisory radio to complement visual signing on highways. The system resulting from the development will operate just outside the upper and lower ends of the AM broadcast band. These frequencies were selected to provide information to the largest number of potential users, motorists with AM radios. However, in the future the cost of AM/FM automobile receivers is expected to be about the same as the cost of AM receivers, and the AM-FM receiver will likely become the standard automobile radio. A choice thus becomes available between the use of the AM or FM broadcast bands.

Proposed Research

1. Study and project the AM-FM automobile radio market trends to determine when the percentage of AM-FM automobile radios will exceed AM radios.
2. Examine the availability of frequencies in or near the FM band.
3. Study the cost-selectivity trade-off to meet the frequency requirements determined without interference with the broadcast channels, TV channels, and educational FM broadcast channels (investigation of the use of the subcarrier frequency may be necessary).
4. Compare the cost and audio quality (bandwidth) expected with the 3-kc bandwidth system developed by the FHWA for operation near the AM band and examine the reliability of communications under different weather and terrain conditions.

6 Automatic Vehicle Identification and Location Techniques for Specific Transportation Applications

Problem Statement

The application of automatic vehicle monitoring (AVM) and automatic vehicle identification (AVI) techniques in specific problem areas has received considerable study. In many of these studies the choice of either AVM or AVI is dictated by the nature of the application. In other cases, however, AVM and AVI techniques may be combined to

produce a more cost-effective system. Many times either AVM or AVI techniques are used without regard to the other type of technology. An examination of specific transportation problems requiring the use of vehicle identification and location could result in a definition of the merits of using either technique or a combination of both for a given type of application.

Proposed Research

1. Analyze the specific transportation problems requiring vehicle identification and location.
2. Define the desired characteristics of the system required to meet this need.
3. Study the characteristics of the available AVM and AVI technology.
4. Study the use of the technology in relation to the desired characteristics.
5. Determine whether AVM or AVI or a combination of AVM and AVI technology is best suited for the specific problem.

Traffic Control Devices*

1 Optimum Standards for Traffic Pavement Markings

Problem Statement

Raw materials used in traffic marking paints are in extremely short supply. Solvents used in these paints have many other uses and are, therefore, subject to worldwide competition. A continual increase in the price of materials and longer delivery times further compound the problem. Extruded thermoplastic, sprayed thermoplastic, and cold applied plastic are now being used for pavement marking; other materials are continually being introduced. Traffic engineers need information on the service life of each type of material and the cost per useful year. Priorities and standards need to be carefully considered and new standards developed, if needed. Standards should be liberalized where possible, consistent with the needs of motorists.

Proposed Research

1. Change the line-to-gap ratio of 3:5 to a new standard, and investigate the use of different ratios for different classes of highways.
2. Reduce the width of all pavement-marking lines, including auxiliary markings.
3. Substitute longer lasting materials for traffic paints.
4. Establish priorities for the installation of all types of pavement markings based on service life of the marking, nature of the marking, and needs of motorists.

2 Delineation of Channelization for Traffic Diversions

Problem Statement

To divert 1 direction of traffic flow from a 2-lane roadway is sometimes necessary, for example, at the beginning of a 1-way flow system where 1 direction is diverted to a cross street and subsequently to a parallel street or at skewed intersections where channelization "bends" the minor street traffic path to intersect the major street at right angles while permitting entry to the minor street along the skew line. These locations require an unexpected and somewhat unnatural change in direction. The problem is believed to be particularly severe at night, when oncoming headlights reduce the visibility of channelization markers and reinforce the unfamiliar driver's expectation that his or her path is straight ahead. In many of these situations, post delineators and channelization curbs are heavily damaged and require frequent maintenance. Research should be done on diversions of one direction of flow on initially undivided facilities and also on sudden diversions, which require placement of an obstruction in the straight-ahead path.

Proposed Research

1. Define the severity of this problem (numbers of such sites, number and severity of accidents at these sites).
2. Identify factors, such as diversion purpose, geometric layout, signs and markings, drivers, and particularly driver expectancy, that may explain why some installations are successful while others are quite hazardous.
3. Develop guidelines for design and marking of such installations.

3 Minimum Level of Effectiveness for Traffic Signs Under Less Than Optimal Conditions

Problem Statement

Most research on traffic signs has been done under optimal conditions (new and clean signs, large signs, less than normal traffic conditions, static viewing) and probably by young engineers or college students, who have better than average visual acuity, are alert, and have been apprised of the study. These conditions are not representative of real-life dynamic roadway and driving situations. Research is needed to determine what minimum sizes and other visibility requirements are needed under actual field use conditions.

Proposed Research

1. Determine whether surrounding luminance levels (daytime, dusk, dark rural, intermediate suburban, lighted urban) have a serious effect on sign visibility.
2. Determine the loss of sign visibility from (a) atmospheric conditions (snow, rain, fog, dust), (b) surface degradation (color fading or darkening, dirt accumulation, reduction in retroreflective brightness), (c) luminaire degradation (dirt, snow, power outage, bulb failure), and (d) density of traffic related to sign size and other visibility requirements.
3. Establish minimum requirements for total sign visibility under real-life dynamic roadway and driver situations.

4 Material Shortages and Their Effect on the Installation and Operation of Traffic Control Devices

Problem Statement

Materials used in traffic control devices are in extremely short supply because of nonuniform price controls, export of raw materials, reduced imports of other materials, diversion of some materials to more profitable products, and other factors. The problem is further compounded by a continual increase in the price of all materials and longer delivery times. Traffic engineers should use materials where the greatest need exists and where the greatest benefit will be derived from the use of the materials. Priorities and standards of all affected traffic control devices must be evaluated and changed. Traffic zone markings, traffic signs, sign supports, traffic signals, and highway lighting should be considered in the analysis. Standards for all traffic control devices should be liberalized where possible or implemented in a different manner. The elimination or reduction of some devices should be analyzed.

Proposed Research

1. Study the effect of reducing the length of the dashed center and lane lines and lengthen the gap between lines.
2. Study the effect of reducing the width of the various types of lines.
3. Establish installation priorities for the various types of markings now in use.
4. Examine ways to extend the use of longer lasting pavement markings.
5. Establish priorities for traffic signs (regulatory signs are usually considered as

first priority, warning signs as second, and guide, information, and directional signs next).

6. Evaluate various methods of sign and post salvage.
7. Review alternate or substitute materials for traffic signs and supports.
8. Develop a priority system for installation of signals and lighting.
9. Establish criteria for placing traffic signals on flashing operation during noncritical hours.
10. Develop a standard plan for turning off all nonessential highway lighting, consistent with acceptable safety standards.

5 Guidelines for Improved Installation of Induction-Loop Wires in Roadway Surfaces

Problem Statement

Almost every user of loop detectors has developed a different method of installing the wires in slots cut in the top surface of the roadway. One or more of the following problems generally develop within a year or two.

1. The wires and the sealing compound work out of the slot, rendering the installation physically dangerous and the detector nonoperative.
2. Moisture seeps down along the edge of the slot and causes either marked leakage from the wire to ground or marked changes in the capacitance of the wire to ground. Either or both of these effects cause false calls, loss of sensitivity, or general instability. This problem is extremely acute when the temperature hovers above and below freezing.
3. The instability and tendency of the surface of some blacktop materials to walk or flow slowly in the direction of vehicle flow cause an associated lengthening of the slot. In many cases the wire cannot stretch to follow the slot bowing and therefore breaks.
4. The mechanical properties of the sealants, the wire, and its insulation and those of the roadway material are entirely different. Therefore, repeated loadings as vehicles roll over the slot combined with environmental changes eventually degrade the installation.

Research Proposed

1. Determine the materials for insulated loop wire and sealants for different road surface materials.
2. Determine the best installation procedures, including the preparation of the slot, pretreatment of the slot, preliminary wire-anchoring procedures, and final sealing procedures.
3. Determine whether a different configuration of the slot might improve the mechanical loading due to the vehicle wheels on the vulnerable interface at the sides of the slot.

6 Shared-Purpose Messages for Changeable-Message Signs During Inactive State

Problem Statement

Some changeable-message signs function for conditions that are not always active (i.e.,

adverse condition warning, traffic condition warning). When functioning for a normal or inactive state, the signs may reduce the confidence of some motorists that the sign functions as a real-time display. Confidence lost in one sign for this reason might be generalized to other changeable-message signs. The same problem could occur when information is of a static nature (nonflashing, nonchanging). Research is needed on ways to improve the confidence of motorists that changeable signs are active and working properly and ways to use general purpose, real-time, or financially advantageous information to accomplish the best improvement.

Proposed Research

1. Study the extent of and reasons for lack of motorist confidence.
2. Test the effectiveness of and investigate the utility and problems associated with changeable-message signs that have time-shared or space-shared dual-purpose displays that include (a) time, temperature, relative humidity, wind velocity, and environmental indexes and (b) changing and static advertising displays.

7 Guidelines for Use of Post-Mounted Delineators

Problem Statement

Post-mounted reflective delineators are used throughout the country as aids for nighttime driving. Unfortunately, the application of the delineation devices is varied and inconsistent from state to state. Although general recommendations for their installations with respect to color and spacing are presented in the Manual on Uniform Traffic Control Devices, more specific standards are required. A consistently applied treatment of roadside delineators would be beneficial to motorists.

Proposed Research

1. Establish warrants or recommended practices for installing roadside post-mounted delineators at both 2-lane and multilane rural highway situations such as curves, tangents, pavement width transitions, exit and entrance ramps, gore areas, and any other geometric features amenable to roadside delineation.
2. Recommend appropriate color, spacing, levels of reflectivity, and maintenance requirements.
3. Consider cost effectiveness of such devices.

8 Location of Guide Signs in Relation to Information Needs of Motorists

Problem Statement

Few standards exist that relate geographic location of guide signs to information needs of drivers. This general problem of location is even further exaggerated when placement points are determined for guide signing in freeway interchanges. Under these operating conditions, the driver requires accurate, timely information. In other words, the geographic location of guide signs must coincide with the driver's decision point for

effective information transmission to occur. If these location requirements are not met, it makes little if any difference how well the sign itself is configured, for the driver tends to seek this information only when it is needed to perform some driving task (such as exiting).

Proposed Research

1. Identify the parameters (in terms of driver information needs) related to the geographic location of guide signs for freeway interchanges.
2. Develop a set of criteria for locating these guide signs such that they correspond to driver information needs.

9 Longitudinal Visibility Distance Requirements for Hazard Markers

Problem Statement

Hazard delineation systems can be classified as either positive or negative depending on the message to be conveyed to the motorist. A positive system provides guidance information concerning where a driver may safely drive; a negative system marks the location where hazards exist and thus indicates where drivers may not drive. Both systems have their proponents and opponents. Should one be adopted over the other, or can useful selection guidelines be developed for specific situations? Marking of hazardous objects such as bridge abutments, trees, culvert headwalls, utility poles, and roadway furniture, within and along the roadway, should be considered. Attention should also be given to possible hazards from traffic aids, such as guardrails and channelization islands.

Proposed Research

1. Define hazard identification and location information that would be useful to drivers and consider hazard type and lateral placement.
2. Determine longitudinal visibility requirements to provide the useful information, e.g., the longitudinal distance at which a drainage culvert headwall, 10 ft from the edge of the pavement, should be visible.
3. Define the adverse effects, if any, of overdelineation of hazards, i.e., whether highly visible hazard markers for objects beyond the shoulder detract from the pattern of positive delineation and add little usable information.
4. Establish guidelines for the selection of appropriate intensities for hazard markers in given situations.

10 Guidelines for the Use of Sign Words and Symbols

Problem Statement

Current sign messages do not always communicate to the driver the message they were designed to communicate.

Proposed Research

Define a minimum vocabulary for signs and a "grammar" for combining words and symbols to (a) be understandable within a maximum permissible comprehension time to the largest possible proportion of motorists and (b) have a consistent relation to the real world to which the signs refer and to other information that the motorist might be expected to have.

11 Energy and Its Effect on Traffic Control Devices

Problem Statement

Electrical energy used to operate traffic signals, changeable-message signs, traffic detectors, highway lighting, and other traffic control devices is in short supply in some areas of the country. The cost to operate electrical traffic control devices is increasing, and conservation of electrical energy is becoming an important consideration in the design of each traffic control device. Traffic control devices must also operate efficiently, for an inefficient traffic signal will cause motorists to wait needlessly and thereby waste precious fuel.

Proposed Research

1. Determine the most efficient method of operation of traffic control devices so that the least amount of electrical energy is used by the devices, consistent with safety for the motorists, and the least amount of fuel is used by motorists.
2. Examine reductions in the amount of light and the hours of operation of highway lighting to conserve electrical energy consistent with accepted safety standards.
3. Evaluate different types and designs of highway lighting for conservation of energy.
4. Evaluate different energy-saving techniques for traffic signal installations.
5. Investigate procedures for placing traffic signals on flashing operation during noncritical hours.
6. Analyze the effect of reduced levels of energy on the operation of traffic control devices.
7. Develop a procedure for determining a traffic signal operation that is most efficient in terms of vehicle fuel usage.

12 Visibility and Legibility Related to Placement of Guide Signs

Problem Statement

What effect does moving a sign 30 ft from the edge of the pavement for safety reasons have on the ability of drivers to locate, read, and react to the sign message?

Proposed Research

Determine what effect the lateral change in the position of signs has on (a) the visibility of the sign by drivers of single vehicles or vehicles in a traffic stream on single and

multilane roadways, (b) the relation of the new sign positions to the established cone of vision, and (c) the height of copy and current established size.

13 Guidelines for Design of Symbolic Sign Messages

Problem Statement

For reflectorized signs to be legible at night, the letters must have satisfactory contrast with the background and have sufficient space between letters to prevent blending of letters due to irradiation. However, some of the new symbolic signs such as those indicating the presence of farm machinery and the crossing of cattle have detailed figures that could easily be blurred by the effects of irradiation.

Proposed Research

1. Develop a supplement to the Manual on Uniform Traffic Control Devices to assist traffic engineers in making symbolic signs legible at the desired distance or in locating the signs such that drivers will have time to react once the sign is legible.
2. Establish minimum width of the finer details and spacing within details of the figure to prevent loss of legibility due to irradiation.
3. Establish legibility-distance to figure-height ratio for each recommended symbol.

14 Design Aids for Preferential and Priority Treatment for Buses on At-Grade Street Systems

Problem Statement

Increased awareness of the importance of developing transit systems has stimulated interest in providing buses with various forms of priority treatment over other traffic. A variety of treatments have been developed and used on at-grade street systems with varying degrees of success. Design aids are needed to assist planners in relating the various priority and preferential techniques available to the scope of the bus service planned, to the capabilities of the at-grade street system, and to the impact on nonbus traffic flow.

Proposed Research

1. Study the relationship among (a) bus service factors, including type of service (line haul, CBD routing of a corridor or freeway bus line, CBD circulation system), frequency of service, bus storage and queuing, passenger management, and loading at bus stops; (b) bus priority and preference approaches, including exclusive direct flow or contraflow lanes, exclusive movement or restriction on other traffic, exclusive or semiexclusive street or right-of-way, special constructions such as bays, traffic signal priority, bus headway controls, and relocation of bus stops; and (c) street system factors, including 1-way or 2-way streets, length of blocks, approach width, volume and capacity, interference with parking facilities, interference with other requirements (such as goods access) for curb lane use, and flow degradation for nonbus traffic.

2. Develop a series of design tools that can provide estimates of bus passenger time improvement and nonbus traffic degradation as a function of the various combinations of parameters described above.

15 Costs and Benefits of Improved Loop Detectors

Problem Statement

The sophistication now developing in traffic control systems and freeway operating systems requires loop detectors that perform better in terms of sensitivity, stability, accuracy, and reliability. In addition to system degradation problems, significant expense is associated with each failure. These include costs of field maintenance groups, repair, and system standby or degradation mode. Military and space technology now available could significantly improve all areas of reliability and performance.

Proposed Research

1. Study the present and proposed usage requirements, including the level of performance and degree of accuracy, for loop detectors.
2. Study the application of military mean-time-between-failures analyses to loop electronics.
3. Structure a cost-benefit model to analyze all of the above considerations of the use of loop detectors on a systemwide basis.

Motorist Information Systems

1 International Signing Standards

Problem Statement

A review and comparison should be made of traffic signing practices throughout the world. Variations in signing practice confuse international travelers and decrease the efficiency of roadway systems.

Proposed Research

1. Determine the means used by countries to convey (especially via symbols) specific messages to motorists.
2. Identify cultural and linguistic reasons for retaining multiple means of conveying a specific message.
3. Prepare an international catalog of research conducted on traffic sign perception and operation and of the philosophies of usage.

2 Definition and Correction of Design Problems on Two-Lane Rural Roads by the Use of Human Factors Approaches

Problem Statement

Certain types of roadway configurations mislead the motorist as to the geometrics of the roadway ahead. Some of these misleading configurations can probably be mediated by the application of signing and marking procedures. Human factors techniques should be applied to define and correct motorist orientation problems specifically in relation to narrow bridges, passing zones on mountain highways, and visually misleading vertical and horizontal alignment.

Proposed Research

1. Identify potential problem locations.
2. Identify the types of motorist problems encountered at these locations.
3. Classify these locations into problem types (i.e., locations amenable to similar treatments).
4. Suggest signing and marking requirements that might result in reliably safe performance for each problem type.
5. Evaluate the performance of the candidate techniques by conducting a series of behavioral field studies.
6. Document the results of these studies in the form of a manual for state and local use.

3 Shoulder Identification on Two-Lane Rural Roads

Problem Statement

During conditions of poor visibility, the motorist needs to know at all times where the

shoulder of the road is located and when he or she is driving on the shoulder.

Proposed Research

1. Identify and evaluate techniques, including contrasting shoulders, rumble-effect shoulders, and varying widths and placement of edge lines, to aid the motorist in locating the shoulder on a 2-lane rural road during conditions of poor visibility.
2. Develop a series of warrants or guidelines for use by local agencies in determining when and how to best use the techniques.

4 Markings and Delineation for Wet and Dry Pavements at Night

Problem Statement

Research on durable and visible markers for wet and dry pavements at night produces new devices and methods every year. Although some problems have been solved, many major problems related to device development and optimum application for effective vehicle control have not been.

Proposed Research

1. Establish minimum visibility requirements on wet pavements at night for various speeds, pavement conditions, and road situations.
2. Determine via empirical laboratory and field research the characteristics of the required roadway markings and delineation.
3. Evaluate the driver's vehicle-handling responses, eye movements, and preferences under the various real or simulated experimental conditions.
4. Prepare a manual detailing the applicability of the acceptable marking and delineation systems.

5 Design Driver and Standards Compatibility

Problem Statement

Highway and traffic engineers have been faced with promulgating standards without having a working specification for the driver. Lacking an adequate operational definition of the driver, highway engineers are unable to match the various highway elements to the attributes of the road user. This in turn may result in operational procedures and designs that are less than optimum and that have incompatible standards. The need exists, therefore, to develop standards and specifications for a "design" driver.

Proposed Research

1. Determine from the existing literature the characteristics of the driving population relevant to the design decisions that are made by traffic engineers.
2. Review the perceptual, physiological, cognitive, attitudinal, personality, and experimental characteristics of the driving population.

3. Catalog driver performance and preference standards (possibly displayed as percentile distributions along characteristics such as reading ability, dynamic visual acuity, and arm reach).

6 Standards For Passing and No-Passing Zones

Problem Statement

Practices and regulations related to the control of one vehicle overtaking and passing another on a 2-lane roadway have evolved during the years by trial and error, personal preference, and some specific research studies. The result is variation among states, inconsistencies in the criteria for applying each of the several traffic control devices, and laws that are not in tune with the needs of drivers or with the meaning of control measures specified by traffic engineers.

Proposed Research

1. Analyze records of accidents at locations with varying characteristics such as sight distance and grade.
2. Establish a set of standards based on safety and vehicle-performance characteristics for the control of passing on 2-lane roadways, including where drivers should be prohibited from passing, where passing would be hazardous but could be safely done under certain conditions, and where safe passing conditions are obvious.

7 Vehicle Forward-Lighting Systems and Sign Location

Problem Statement

Several studies have provided data on laterally offset shoulder-mounted signs and patterns and aiming characteristics of vehicle headlights. Data are lacking, however, on the problem of overhead-mounted signs. Further, the question of compatibility of vehicle forward-lighting systems and sign placement as specified in the Manual on Uniform Traffic Control Devices has not been assessed.

Proposed Research

1. Determine the effects of overhead sign mounts on sign legibility for low- and mid-beam forward-lighting systems.
2. Use data from these empirical studies and data from existing lateral offset studies to determine whether and to what extent incompatibilities exist between vehicle forward-lighting systems and sign placement and legibility standards.

8 Trip Planning Ability of Motorists

Problem Statement

The ability to plan a trip and execute this plan in transit is an important navigational skill that may be lacking or deficient in a large segment of the population. Although this ability has a great effect on the comfort and convenience of the trip, little has been done to provide drivers with the training needed to perform this task.

Proposed Research

1. Determine the problems and materials (maps, written statements) associated with conventional route planning by various subpopulations of drivers based on biographic information (age, sex) or vehicle or trip characteristics (motorcycles, tourists).
2. Identify the potential route-planning procedures that would remedy the problems encountered by specific driver populations.
3. Evaluate these procedures in the laboratory and where possible in the field.

Visibility*

A nationwide survey of fixed-source highway lighting practice was completed by the Committee on Visibility in 1973 and published as Highway Research Circular 149. Several states suggested areas of research needs related to fixed-source highway lighting, and these are given in that circular on pages 30-37.

1 Average Maintained Lighting Level for Interchange and Continuous Freeway Lighting Systems

Problem Statement

There has been considerable public reaction, particularly since the energy shortage, to the brightness of newly installed lighting systems on freeways. At this time, the level may be in the order of 1.2 to 1.5 ft-c (12.9 to 16.1 lm/m^2), having been designed to an end-of-rated-life (ERL) level of 0.6 to 0.8 ft-c (6.6 to 8.6 lm/m^2). The question is, Should design be to an ERL level this high, or would some lower level be sufficient to accomplish the seeing task and thereby to reduce the initial level at the time of installation?

Proposed Research

1. Analyze existing deteriorated systems, where the footcandle (lumen/square meter) level has been determined and possibly construct a test system where the level can be varied for analysis purposes.
2. Determine whether the minimum level required is the same for high mast lighting [80 to 120 ft (24.4 to 36.6 m)] as for conventional lighting [30 to 50 ft (9.1 to 15.2 m)].
3. Determine whether the minimum level required is the same for continuous freeway lighting as for interchange lighting.
4. Determine whether various pavement compositions (e.g., concrete versus bituminous) have sufficient effect on the nighttime seeing task to require different minimum levels for each condition.
5. Determine whether the various types of lighting (e.g., mercury vapor versus high-pressure sodium) have any effect on the minimum levels required.

2 Pavement Reflectance Characteristics for Typical Highway Surfaces

Problem Statement

Lighting engineers need to apply the luminance of the highway surface in lighting calculations but cannot because of lack of knowledge of reflectance properties of pavements that are known to have satisfactory skid-resistance properties.

Proposed Research

1. Collect dry, damp, and wet pavement reflectance data on 200 to 300 samples of pavements throughout the North American continent.
2. Analyze the data to determine the confidence limits applicable to use within each

pavement classification.

3. Develop and disseminate computer programs to facilitate use of the collected data.

4. Develop and publish practical examples or case studies to demonstrate use of the data and methodology.

3 Highway Lighting to Produce Even Luminance

Problem Statement

Light reflected toward the driver is the critical feature in seeing. Thus, luminance rather than illuminance is the important consideration. Highway lighting is measured in terms of luminance in Holland, but still in terms of footcandles of illumination in the United States. A method of providing even luminance is needed to enable drivers to better see obstacles.

Proposed Research

1. Determine a method by which lighting and highway surfaces can be specified to provide uniform luminance for the driver under average night driving conditions.
2. Review and apply, where applicable, methods used in other countries.

4 Accident Reduction Through Use of High-Mounted Running Lights and Repeater Signals

Problem Statement

Persons involved in automobile and pedestrian accidents regularly report that they did not see the accident developing until it was too late to avoid it. Studies show that the use of daytime headlights, parking lights, and auxiliary running lights reduces accident capabilities 10 to 37 percent, yet no test has been made of the accident protection provided by properly designed high-mounted running lights and repeater signals. Clearly, there are important but ignored visual factors involved in motor vehicle accidents.

Proposed Research

1. Test improved running light and signal systems to assess their accident-prevention ability and give special attention to fleet studies and isolated community studies.
2. Undertake a study of accidents in which matched sets of a large number of test and control vehicles are used during an extended period.
3. Analyze the problems involved and develop a plan for introducing an improved automobile running light and signal system into the vehicle population.

5 Fixed-Lighting and Vehicular-Lighting Systems to Provide Target Detection and Driver Comfort

Problem Statement

Aspects of the combined use of fixed-lighting and vehicular-lighting systems are contradictory. Information is needed on how to design the systems so that they complement each other.

Proposed Research

1. Use standard light distribution from fixed sources and directional or semidirectional fixed-light distributions to determine driver visibility and comfort requirements.
2. Correlate these light distributions to rough, highly skid-resistant pavement surfaces.
3. Correlate these light distributions to the expected weather conditions (rain, fog, snow).
4. Check their performance when used in conjunction with directional vehicle headlighting.
5. Develop practical, inexpensive ways to eliminate from the driver's way the light from oncoming vehicle headlights.

6 Retroreflectors to Protect Pedestrians at Night

Problem Statement

About 20 percent of all motor vehicle accident deaths are pedestrians. Pedestrians are struck at night by motorists, 80 percent of whom report that they did not see the pedestrian. Field studies by the Division of Optometry of Indiana University indicate that pedestrians estimate themselves to be several times more visible than they in fact are. Other tests show that, when low-beam headlights are used on a clear night with no glare, traveling 40 mph (64 km/h) is too fast for a motorist to see the average pedestrian and to avoid an accident. However, if pedestrians were wearing reflectors, a motorist might see them in time to stop even at higher speeds and even though only low beams were being used.

Proposed Research

1. Study the effectiveness of the use of retroreflectors on a sample of pedestrians as a means of reducing nighttime vehicle-pedestrian accidents.
2. Recommend a procedure for implementing a pedestrian protection program for the entire U.S. population.

7 Subjective Scale for Describing Degrees of Visibility as Observed by a Driver

Problem Statement

There is no common verbal description of visibility related to highway driving conditions

as there is in aviation. That verbal description of visibility, which is useful to pilots, is based on meteorological measurements. Highway drivers would likely find such a description useful in many ways.

Proposed Research

1. Evaluate the aviation terminology for describing visibility to determine whether it might be applicable for highways.
2. Consider the desirability of making the scale in terms of stopping distance or stopping time or both.
3. Evaluate different terms for daylight and darkness, i.e., low beam-high beam effect from precipitation.
4. Make pilot survey in which new terminology is used to determine its usefulness and clarity of interpretation.
5. Make proposals appropriate for consideration by private and public agencies interested in application of such a scale to accident prevention activities.

8 Appropriate Combination of Vehicle Lighting and Fixed Lighting for Urban Roadways

Problem Statement

The nighttime visual environment produced by present fixed lighting and present vehicle headlights is neither safe nor cost effective. Vehicle headlights are designed for lighting roads without fixed lighting. In urban areas where fixed lighting is needed for many reasons other than vehicular traffic, the role of vehicle lighting changes from illumination requirements to delineation requirements. Headlights are generally not compatible with fixed lighting. Limited experiments show that 2 ft-c (21.5 lm/m^2) of fixed lighting in combination with parking lights produced greater visibility distances than fixed lighting in combination with low- or high-beam headlights. The glare from oncoming headlights reduces visibility and also produces unnecessary discomfort. The cost of operating headlights is significant and should be taken into account when the cost of producing the safest and most economical nighttime driving environment is determined, especially in view of the fact that more than 75 percent of the population lives in urban areas where there is approximately 10 percent of the national roadway mileage.

Proposed Research

1. Determine costs of present fixed lighting on urban roadways.
2. Determine costs of adequate fixed lighting without the use of headlights.
3. Determine nighttime vehicular mileage and average speeds for different classes of urban roadways.
4. Determine present vehicle headlight operating costs per hour.
5. Analyze combined cost of appropriate fixed lighting and appropriate vehicle parking or marker lighting.
6. Analyze accident costs on roadways (poor, fair, adequate) with fixed lighting and without fixed lighting.
7. Estimate potential accident reduction and economic savings with appropriate fixed lighting and vehicle marker lighting in urban areas.

Railroad-Highway Grade Crossings*

1 Driver Reactions to Active Warning Systems at Existing and Improved Grade Crossings

Problem Statement

Some 40 percent of all vehicle-train collisions occur at the 20 percent of the grade crossings where there are train-activated warning devices mainly because rail and highway traffic volumes are higher at these crossings. Because of this high accident rate, the best means of alerting the driver and of eliciting the proper response needs to be determined. In addition, costs need to be lowered so that more crossings can be actively protected within a limited budget.

Proposed Research

1. Establish driver reaction to color, brightness, movement, flash rate, and signal area as affected by the visibility and attention-attracting properties of warning devices.
2. Establish minimum conspicuity levels for warning devices under both day and night conditions to meet time-distance requirements.
3. Investigate specifically driver reaction to the following warning systems: red/amber/green traffic signals, variable-message signs, and Xenon flashing lights.
4. Establish the amount of variation in warning time that drivers will accept without losing confidence in the warning device.
5. Study the effect of gate-arm conspicuity and activation times on driver behavior.

2 Implications and Effects of Civil Liability on Railroad-Highway Grade Crossing Safety

Problem Statement

Technical solutions to grade-crossing safety problems are restricted by liability considerations. Hardware development is retarded by the requirement that devices adhere to a particular fail-safe concept and by the low-voltage lamps dictated because of requirements for battery backup power. Because of potential legal liability, there may be reluctance to experiment with new designs and to establish warrants for crossing improvements, whether presented as guides or requirements. The failure to have a crossing protected in accordance with such guides may leave a railroad company and a responsible public body liable. There is a reluctance to prescribe minimum requirements for marking railroad locomotives and cars, since in case of an accident the condition of the markings could well be an issue. Liability issues can result in a lack of candor on the part of surviving drivers and railroad companies in reporting grade-crossing accidents.

Proposed Research

1. Identify specific liability issues, including actual experience with juries and magnitude of settlements, and all areas in which liability considerations restrict or inhibit possible safety measures.
2. Evaluate existing legislation and other actions that relate to liability as they apply to the highway user and the railroad.

3. Analyze alternative, innovative solutions to the liability problem, including governmental installation and maintenance of devices.
4. Develop a model law that incorporates improvements in a single compatible system.

3 Grade-Crossing Warning Displays as Related to Alternative Fail-Safe and Malfunction Displays and Standby Power Concepts

Problem Statement

If the present fail-safe concept is used, the same warning to the motorist is activated by equipment malfunctioning as by the presence of a train. If warnings are too often activated unnecessarily because of system malfunction, credibility and therefore effectiveness of the warning are weakened. Standby power concept has not been modified since the 1920s when commercial power was unreliable in urban areas and nonexistent in rural. Present visual displays are designed to accommodate the limitations imposed by the use of batteries.

Proposed Research

1. Assess the degree to which the effectiveness of the grade-crossing warning is diminished by unnecessary activations.
2. Determine the technical constraints on malfunction indication (power consumption, visibility).
3. Determine the driver-information requirements to be met by indications of malfunction or power failure or both, and assess the relative effectiveness of positive malfunction indications and absence of indications normally present.
4. Develop a malfunction and power failure indication system to meet these requirements.
5. Assess the reliability of commercial power today in various circumstances (urban, rural, climatic zones) in terms of number and duration of failures per year.
6. Assess the limitations imposed on signal displays by low voltage requirements and the use of battery.
7. Evaluate potential improvements in signal displays that require greater voltage.
8. Based on this analysis, propose an optimum system for standby power.

4 Driver Education Curriculum Material and Mass Media Information on Grade-Crossing Safety

Problem Statement

Although a wide variety in amount and type of information is now included in driver education curricula and in driver licensing manuals, a recent study of driver knowledge of, attitude toward, and behavior at railroad-highway grade crossings identified a need to provide more or better guidance to drivers on how to safely negotiate crossings. Many grade-crossing accidents may be attributed to some lack of understanding of the driver's responsibility at grade crossings.

Proposed Research

1. Analyze tasks required of drivers approaching and arriving at grade crossings.
2. Analyze the causes of vehicle-train accidents.
3. Review existing educational materials.
4. Analyze drivers' understanding of grade-crossing hazards.
5. Develop countermeasures and undertake tests in selected areas.
6. Determine the most effective material to include in driver education curricula, driver licensing manuals, and mass media campaigns.

5 Train Visibility and Conspicuity at Railroad-Highway Grade Crossings

Problem Statement

In more than 30 percent of all vehicle-train accidents, the vehicle strikes the side of the train. At night this percentage increases to more than 40 percent. Although some of these are close enough to the front of the train to indicate that visibility of the train on the crossing itself might not have been a factor, the high frequency of this type accident farther back in the train indicates failure of the motorist to see the train already occupying the crossing.

Proposed Research

1. Analyze the existing accident history and identify the magnitude of the problem in rural and urban areas for active and passive crossing protection.
2. Review existing practice in freight car marking, locomotive lighting, and crossing illumination.
3. Evaluate the cost and effectiveness of crossing illumination including light patterns to determine the optimum design for rural and urban areas.
4. Analyze the relative merits and cost effectiveness of all available methods of reducing accidents in which the vehicle impacts the side of the train.
5. Recommend a course of action for implementation of the best system.

6 Quadrant Sight Distance at Grade Crossings

Problem Statement

Restrictive sight distance at grade crossings is hypothesized to be a contributory factor in many accidents. Maintenance of adequate sight distance often involves private property, which is beyond the control of the railroad company or highway department.

Proposed Research

1. Review available literature and analyze accident data on the effect of sight distance on accident probability.
2. Analyze costs and benefits of improving sight distances on the highway and railroad right-of-way.

3. Investigate and evaluate methods of improving sight distances by altering and maintaining sight distance across private property (possible methods include lease private property and mow or remove shrubs, purchase property, pay farmer for high crops not raised in quadrant, remove lower branches of large trees, regrade property, and analyze cost of such leases or payments versus benefits).

7 Operations of Special Trucks and Buses at Grade Crossings

Problem Statement

Trucks carrying hazardous materials, school buses, and other buses are required to stop at all railroad crossings. This stopping often disturbs traffic flow and contributes to vehicle accidents. The increased exposure time and possibility of stalling the engine also increase the hazard in many instances. Research is needed to analyze and evaluate the various methods of operation of special vehicles at grade crossings. These methods include special routing, use of pullout lanes, and designation of certain crossings as exempt.

Proposed Research

1. Identify jurisdictions where each of the various methods are being used.
2. Analyze the cost and benefit of each method, including accident data.
3. Discuss the institutional, administrative, and legal problems involved with each method.
4. Recommend a course of action.

Vehicle Characteristics

1 Vehicle Operating Characteristics Related to Design Parameters for Secondary Stopping and Off-the-Road Recovery

Problem Statement

The design of highways is based partially on vehicle operating characteristics that were developed in the middle and late 1950s. Therefore, the question is raised as to whether the vehicles now in traffic streams have the same operating characteristics as those used to develop many of the design parameters related to acceleration, deceleration, and stopping. A subsequent question is whether we need to review the design parameters that were based on the 1950 vehicles to ensure that the real world is represented in designs.

Proposed Research

1. Analyze the current vehicle operating characteristics related to the actions of secondary stopping and recovery off the roadway.
2. Determine the degree of difference, if any, between the vehicle operating characteristics in the 1950s and today.
3. If any differences are found, study and evaluate their effects on design parameters relating to secondary stopping and recovery off the roadway.
4. Determine what changes are needed in the design parameters and prepare new design parameters as required.

Road User Characteristics

1 Restriction of Driving by Elderly License Holders

Problem Statement

Elderly drivers experience a highly disproportionate number of accidents in relation to the amount of driving that they do. Because the aging process is not uniform among drivers, measures that would restrict older drivers indiscriminately are neither fair nor feasible. However, better information on the kind of driving that appears to be most hazardous for older drivers would provide a basis for judicious restrictions on their driving. Restrictions would be individually determined and not based on age alone.

Proposed Research

1. Determine the types of driving that are associated with elevated risk of accident for elderly drivers.
2. Determine the extent to which the drivers involved in these accidents may differ from other drivers of the same chronological age.
3. Investigate the feasibility of developing a procedure for predicting which older drivers present the greatest risk.
4. If possible, develop a reasonable procedure for identifying such drivers at the time of driver license renewal examination.
5. Develop and implement procedures for placing restrictions (limited licenses) on such drivers.
6. Monitor the extent of compliance with such restrictions.
7. Evaluate the effects of limited licenses for selected elderly drivers.

2 Classification and Quantification of Roadway and Environmental Disturbance Inputs to the Driver-Vehicle System

Problem Statement

Increasing emphasis is being placed on quantifying driver performance and vehicle-handling properties in a variety of driving situations, tasks, and maneuvers. Yet, such situations and tasks are ill-defined, particularly when they involve disturbances that originate from the roadway environment external to the vehicle. For example, such disturbances can arise from aerodynamic inputs (terrain, roadside structure, ambient turbulence), roadway geometry and anomalies (bumps, dips, surface texture variations), visual effects (glare, shadows, contrast), and acoustical sources (wind, other vehicles). Disturbances from these and other sources can change or degrade vehicle handling, directly influence the vehicle's motion and trajectory, disrupt the driver's perceptual processes, and cause inappropriate or inadequate driver control actions that in turn degrade performance. These disturbances can be discrete, single events, or they can be more random ongoing processes describable in statistical and spectral terms. Programs for design and maintenance of roads and for improvement of driver performance and vehicle handling could benefit from this study.

Proposed Research

1. Review and summarize relevant portions of the literature and existing data related to disturbance inputs, driver tasks, driver response and performance, and vehicle-handling effects.

2. Classify disturbance inputs according to a logical scheme, such as the nature of their effect on driver-vehicle response and performance.
3. Establish mathematical models and appropriate forms for data quantification and use.
4. Define data needs related to quantifying disturbance parameters and assessing frequency of occurrence and importance.
5. Establish priorities, by data type, for collection and evaluation.
6. Based on these results, collect needed data to quantify disturbances and their probability of occurrence.
7. Interpret the data and report it in operational form, suitable for application to analytical and experimental investigations of driver performance and vehicle handling.
8. Demonstrate the use and applicability of the results with example applications.

3 Perception-Reaction Time as a Factor in Accident Involvement

Problem Statement

There is evidence of wide individual differences in perception-reaction time (PRT), and the issue of PRT is continually being raised in the course of accident investigations and litigations as a possible causative factor. Traffic manuals frequently cite PRT as a design justification. No definitive literature exists on this point; indeed, opinions that have been expressed regarding the relation between PRT and accident occurrence are dramatically opposite. Some evidence has been presented that suggests strongly that a relation does, in fact, exist; however, this evidence is slight and requires confirmation (or refutation). Therefore, a logical assumption is that a driver with a grossly deficient PRT will be at a disadvantage in an emergency driving situation. A definitive study of this problem is long overdue.

Proposed Research

1. Select a large, representative sample of drivers and administer selected vision tests to provide control data and a PRT test.
2. Collect sufficient accident record data and exposure data for the drivers thus tested.
3. Analyze the relation between PRT and accident record, controlling for age, sex, vision, and exposure.

4 Influence of Drugs on Driving Accidents

Problem Statement

The presence of drugs in automobile drivers may increase the probability of accident involvement. Specifically, individuals under the influence of drugs such as marijuana, barbiturates, and amphetamines have made subjective reports that drug effects lead to accidents or near accidents. Furthermore, simulator studies have found performance impairment from drugs such as tranquilizers, barbiturates, and opiates. This hypothesis is further supported by several epidemiological studies, which have found the

presence of drugs to be greater in accident victims than in the driving population at large. A series of studies involving both epidemiological investigations and laboratory research are required to determine the degree to which these drugs contribute to accident production.

Proposed Research

1. Compare the frequency of drivers who show presence of drugs and are involved in accidents with the frequency of control subjects who are passing the site of an accident and show presence of drugs and simultaneously examine the nature of the accident to determine how the presence of various drugs contributes to the causal accident mechanism.
2. Examine the influence of these various drugs on performance factors important for driving.

5 Driver Skill and Tractive Force Demands at Road-Tire Interface

Problem Statement

As traffic densities increase, the tractive force demands on the road-tire interface to allow safe driving also increase. When the tractive force demanded exceeds the available tractive force, an unsafe skidding condition occurs. A skid can be the result of one or several factors involving the driver-vehicle-highway system. For example, the pavement may be rain soaked and smooth, the tires may be excessively worn, or the vehicle velocity may be excessive. Of the many factors that influence a skidding situation, those associated with determining available tractive force have received the most study (i.e., supported by automobile industry, tire industry, and government on vehicles, tires, and pavements). Tractive force demands generated by road users, particularly the influence of driver skill on tractive demands, have received little study. However, driver skill or the variability of driver skill must be an important factor in determining tractive force demands in high demand maneuvers when skids are likely to occur. Therefore, the objective of the research is to establish an initial quantification of the influence of driver skill on the generation of tractive force demands for simple lateral and longitudinal vehicle maneuvers.

Proposed Research

1. Review the literature to determine with respect to skidding and skid-related accidents (a) the types of vehicle maneuvers most frequently involved; (b) the important features of highway geometry, alignment, and delineation; (c) the implications of environmental factors (rain, pavement water depth, ambient light levels); and (d) those characteristics of the driving population (age, driving experience, visual capacity, motor coordination) that appear most relevant.
2. Use the results of the literature review to specify the types of maneuvers (including driver, pavement, geometry, and environmental parameters) needed to investigate the relation between driver skill and tractive force demands.
3. Conduct field tests of the operationally specified maneuvers while maintaining the internal and external validity of the experiment.
4. Analyze the data quantifying the relation between maneuver and driver skill in terms of tractive force demand and attempt to determine situations, if any, in which driver skill is the dominant or crucial factor.

6 Comparison of Behavior of Safe Drivers and Highly Skilled Drivers

Problem Statement

The purpose of this research is to get a better understanding of the dimensions of the driving task by focusing on the differences between highly skilled driving behavior and defensive driving behavior. Highly skilled drivers have the ability to react quickly, maneuver in difficult situations, estimate speed and distances effectively, and maneuver the vehicle skillfully. Defensive drivers use proper caution, estimate risks and choose safe options, attend to traffic rules and laws, drive without being intoxicated or handicapped, and exhibit noncognitive attitudes toward driving that tend toward high safety performance, but not necessarily highly skilled performance.

Proposed Research

Study 3 classes of variables including (a) safe driving judgment factors and skilled driving factors and their interdependencies and exclusive characteristics; (b) driver population descriptions (e.g., for each driver type, either safe or skilled, experience in years, sex, commercial, private, and vehicle use patterns, age group, violator or nonviolator status, and accident experience); and (c) environmental and situational factors that affect the first class of variables from the point of view of difficulty and quality (night versus day, weather, traffic density, and age or youth as a modifier of criteria and needs).

7 Self-Diagnosis and Self-Study as a Technique for Reeducation of Problem Drivers

Problem Statement

In spite of the statistical and chance factors involved in determining which violators are identified and required to attend retraining classes under the point system, such classes can serve a useful function. Although professionals generally consider "blood and gore" movies to be offensive and counterproductive, such movies are still used indiscriminately for all types of offenders in some jurisdictions. Meanwhile, evidence continues to indicate that personalized counseling is more effective in changing the behavior of certain types of violators. Counseling per se is expensive, but guided self-study projects using straightforward, factual materials might serve the same purpose.

Proposed Research

1. Summarize the past attempts at self-study or counseling in the treatment of traffic offenders.
2. Rank the effectiveness of traditional punitive and past counseling approaches in influencing future performance.
3. Identify groups or types of violations or offenders that are influenced by each approach.
4. Devise an alternative approach based on the self-study concept.
5. Develop materials for implementing this alternative approach.
6. Test the concept and materials in sample offender-retraining classes.

8 First-Aid and Emergency Medical Training as a Requirement for Driver Licenses

Problem Statement

The highway accident mortality and morbidity rates are somewhat sensitive to emergency rescue and first-aid actions taken at the scene. Some utility companies and companies with truck fleets require their drivers to have first-aid training. Severe burns, spinal injuries, asphyxiation, and heart attacks require immediate, proper decisions by whoever is closest. Who should be trained, to what extent, and by what mechanism have yet to be determined.

Proposed Research

1. Ascertain the extent and frequency of first-aid training among professional road users.
2. Determine the frequency of need for this training.
3. Based on accident, rescue service, and hospital records and data, estimate the potential utility of training.
4. Identify relevant categories of road users and determine an optimal level of training for each.
5. Investigate methods for conveniently and economically providing training at each level.
6. Recommend further improvements in data base, procedure, or training mechanisms.

Pedestrians

1 Involvement of Aging Pedestrians in Traffic Collisions

Problem Statement

Persons over 65 years of age are involved in a large portion of pedestrian collisions with moving vehicles. The trend toward development of housing areas that are populated by those over 65 compounds the problem.

Proposed Research

1. Determine reasons why aging pedestrians have such a high involvement in pedestrian-vehicle collisions.
2. Design investigations to reveal transportation needs of aging pedestrians in various types of living environments, physical capabilities that affect pedestrian performance, and capabilities that may be improved or corrected.

2 Bicycle Accident Data System

Problem Statement

Appropriate methods are needed for accident reporting of bicycle-motor vehicle, bicycle-bicycle, and bicycle-pedestrian collisions. The operation of bicycles on major city streets and highways has increased tremendously in the past 2 or 3 years and has led to a corresponding significant increase in reported deaths and injuries. Almost 1,100 deaths a year are now being reported as a result of bicycle-motor vehicle collisions; in 1963 the number was 850.

Proposed Research

1. Analyze the nature and frequency of occurrences of incidents.
2. Determine the variables that are involved in bicycle-related collisions.
3. Determine the degree of accident reporting procedures that currently account for these variables.
4. Study and evaluate various methods and techniques that will ensure a reliable reporting procedure concerning bicycle-related collisions.
5. Prepare sample accident reporting forms, procedures, and guidelines.

3 Effects of Painted and Unpainted Crosswalks at Intersections

Problem Statement

A 1970 study in San Diego found that unmarked crosswalks were safer than marked crosswalks. The study offered the explanation that pedestrians were more alert when crossing at intersections where no lines were present to "protect" them. It should be determined whether the results were unique to San Diego and conditions existing during the study of whether they are applicable to all metropolitan areas.

Proposed Research

Determine the positive or negative contribution of painted pedestrian crosswalks to pedestrian safety (widespread studies should be based on the research design used in the 1970 San Diego study).

4 Relation of Legal Right Turns on a Red Signal and Pedestrian-Vehicle Collisions

Problem Statement

Many states are considering the passing of a traffic law that permits a right turn on a red signal to expedite movement of vehicular traffic. Such decisions should be made with full awareness of the effect on pedestrian and vehicle collisions.

Proposed Research

1. Match a variety of intersections where right turns on a red signal are allowed.
2. Compare matched cities in states that either do or do not permit drivers to make a right turn on a red signal.

5 Instructional Treatments to Improve Pedestrian Behavior of School Age Youths

Problem Statement

Pedestrian-vehicle conflicts continue to be one of the major causes of death and injury of school age youths. Experience and limited research indicate that mere learning of safety rules may not be effective in ensuring desirable pedestrian performance in traffic. Instructional treatments that place emphasis on fear techniques tend to have either short-term or negative benefits. The problem is further complicated by the natural inability of youth to perceive hazards and by their undeveloped reasoning processes.

Proposed Research

1. Develop 3 instructional treatments that emphasize (a) rule-learning instruction that has a balance of dos and don'ts, (b) rule-learning instruction that uses fear techniques, and (c) goal-oriented instruction that stresses hazard perception, risk assessment, and decision making.
2. Equate the instructional treatments for amount of practice, time allocation, and scheduling practices.
3. Select 3 school jurisdictions that have similar socioeconomic conditions, traffic environments, police traffic supervision, and quality of education.
4. Implement the 3 instructional treatments to randomly selected groups of students with stratification for sex, race, grade point average, and other pertinent factors.
5. Compare the 3 groups in regard to frequency and severity of pedestrian-vehicle collisions for a 2-year period after the instruction.

6 Design Alternatives for Pedestrian Accident Countermeasures

Problem Statement

Each year, a great many pedestrians are killed or injured in conflicts with automobiles. In 1972, 400,000 pedestrians were killed and injured. Of these, 350,000 pedestrian accidents occurred in urban areas. Many countermeasures have been recommended to alleviate or reduce the high numbers of pedestrian casualties. Research studies have revealed that some of these countermeasures induce safer pedestrian and vehicle operator behaviors. A recent study indicates, however, that many of the most effective countermeasures posed maintenance problems and were judged to be aesthetically unacceptable by the users and residents of the area. Thus, although procedures for reducing pedestrian accidents are available, their use is contingent on their acceptance.

Proposed Research

1. Determine the behavioral objectives of the existing countermeasures vis-à-vis pedestrians and motorists.
2. Review the design of existing pedestrian accident countermeasures.
3. Determine design objections to the existing countermeasures.
4. Based on this analysis, redesign the existing countermeasures.
5. Determine the proper materials and equipment needed to implement the designs.
6. Prepare design specifications and fabricate the most promising redesigned countermeasures.
7. Field test the new pedestrian accident countermeasures for behavioral and acceptance characteristics.

7 Behavior of Pedestrians and Cyclists

Problem Statement

A meaningful, useful behavioral taxonomy that would serve many purposes relating to pedestrian bicycling behavior needs to be developed to be used as a source of basic information for all planning function and design discussions.

Proposed Research

Identify the behavior of segments of the walking and cycling population, their situational contexts, and their life roles (family, work, leisure) to form a data base of descriptive and explanatory information.

8 Visual and Psychomotor Skills of Small Children and Their Involvement in Traffic Accidents

Problem Statement

Traditionally, most accidents have been assumed to be caused by lack of knowledge of or disobedience to laws and rules. Recently, however, educators have become

increasingly aware that specific types of learning problems in early childhood are due to lack of physical skills such as visual and physical coordination. A question then is, Do young children have the physical capabilities to operate safely and efficiently in the traffic environment?

Proposed Research

1. Determine the extent to which the lack of basic visual and psychomotor skills is a causal factor in child-related traffic accidents.
2. Analyze the nature and frequency of child-related traffic accidents.
3. Identify those visual and psychomotor skills that are necessary in the child pedestrian task.
4. Identify child skill (potentials and limitations) capabilities in relation to task demands.
5. Study and analyze present education practice and efforts in light of findings.
6. Identify several counterapproaches to the problem.

9 Critical Tasks of Pedestrians

Problem Statement

Present pedestrian training is situational and provides little understanding of the critical tasks the pedestrian must master or the commonalities among the subtasks. The important target groups have substantial limitations in both learning and perceptual-motor capacities, and this implies limitation in what can be taught effectively. It is essential to identify the most critical pedestrian tasks in order to concentrate educational efforts upon them.

Proposed Research

1. Analyze urban and rural walking tasks into behavioral units.
2. Rate tasks for criticality with reference to accident statistics, research studies, and expert opinion.

10 Pedestrian Accident Reports

Problem Statement

Few accidents are investigated; most are merely reported. Those accidents that are merely reported are not reported adequately for research purposes. Because investigated accidents make up such a small sample of all accidents, much of the data required for meaningful research may not be available. A method is probably needed for reporting officials (as opposed to accident investigators) to collect more of the available data in a routine manner. Police and traffic engineers would then have more useful recommendations derived from more valid research findings, particularly in the case of pedestrian accidents.

Proposed Research

1. Determine the investigated and merely reported ratio of pedestrian accidents.
2. Develop data requirements for research areas.
3. Determine the sampling requirements for accepted confidence levels of statistical inference.
4. Identify pertinent collected data and available, but uncollected, data.
5. Determine the simplest and most effective method for reporting officials to collect the additional data.
6. Develop forms and procedures to collect the data.

Motorist Services

1 Combination Service Station and Rest Area on Interstate Highway System

Problem Statement

Existing rest areas are difficult and expensive to maintain properly. Off-road services are difficult to find in many areas. Existing statutes prevent service stations on Interstate Highways. The basic problem is how to provide adequately for rest areas on rural freeways within financial and legal constraints.

Proposed Research

1. Identify the magnitude and location of problems.
2. Review adequacies and inadequacies of existing facilities on Interstate Highways.
3. Review adequacies and inadequacies of existing facilities on toll roads and parkways.
4. Develop recommendations to more adequately meet the need for rest areas on rural freeways.

2 Standards for Rest Areas

Problem Statement

Travel forecasts show that approximately 20 percent of all future travel in the United States will occur on approximately 1 percent of the arterial, expressway, and freeway systems. The impact of travel in terms of both congestion and its influence on local and regional economics has long been known. This impact is severely felt in the thousands of rest areas that have been developed along these roadway facilities. A knowledge of the travel habits and characteristics of road users who stop at these areas would provide valuable insight in establishing design standards for future rest areas and for general interchange planning and location.

Proposed Research

1. Accumulate data based on (a) a literature search on the topic; (b) identification of a roadway or roadways that have a large number of rest area facilities that provide a range of services from minimum accommodations of parking areas only to the maximum accommodations of restaurants and truck services including fuels, scales, icing, mechanical services, rooms, showers, and TV lounge; and (c) identification of the trip purposes, reasons for stopping (information, convenience, safety), geometric design of the roadway and parking facilities including length of acceleration and deceleration lanes and the effect on operations, pet walking areas, and playground facilities.
2. Identify the cost effectiveness of the publicly and privately owned and operated rest area facilities.
3. Identify the services most required under given sets of roadway and traffic conditions.
4. Establish the optimum location for rest area facilities and services to be provided and identify the trade-off that might be made if the optimum location is unobtainable.
5. Determine the extent that services for the 3 functions of a rest area (safety, convenience, and information) should be provided on the various types and classifications of roadway facilities.

6. Establish the location and dimensions of pet walking areas.
7. Develop guidelines for the design and operation of rest areas similar in format to the manual, A Policy on Geometric Design of Rural Highways, prepared by the American Association of State Highway Officals.

3 Uniformity in Providing Routine Motorist Services: Pricing of Towing Services

Problem Statement

Prices charged by tow truck operators that provide needed services to motorists are not uniform. Many times a motorist has no choice but to accept the needed services at the price charged or remain stranded. Because there is no satisfactory way to control prices for services rendered, a research program should be conducted to establish guidelines for pricing tow services for disabled motorists. The objectives of the research would be to develop a uniform system of determining charges by tow operators to disabled motorists.

Proposed Research

1. Determine how many tow operators follow a fixed price schedule and how the scheduled prices are developed.
2. Determine the number of states that contract with independent garages and the contract prices for towing.
3. Determine from the major automobile clubs the overhead cost and profit margin of maintaining a tow vehicle and the charges for tow service.
4. Establish a need for a uniform fixed-price schedule on routine tows involving disabled motorists.
5. Establish whether there is a need for all states to contract for tow services on turnpikes and Interstate and U.S. highways.
6. Establish statistical data on the operational cost of maintaining tow vehicles (this information can then be released to independent tow agencies for their evaluation to determine whether they can operate within a uniform fixed price).

4 Uniformity in Providing Routine Motorist Services: What Service to Provide?

Problem Statement

An evaluation is needed of the motorist aid services that are provided by public and private agencies throughout the United States. These include police departments, courtesy patrols, highway maintenance personnel, private garages, and private tow operators. Limited research has been conducted to ascertain which service would be the best for the least operational cost under various conditions. An agency contemplating a new system, however, needs assistance in determining what services to provide and how to provide them, and agencies already providing services need to periodically reevaluate them.

Proposed Research

1. Compile accurate data on types of motorist aid services that are available in metropolitan and rural areas, agencies providing the services, average time requirements for various services to arrive, motorist service calls that are urgent in nature, cost of providing services, and public acceptance of the services and interagency cooperation.
2. Make a comparative analysis of the various types of services.
3. Establish a uniform need for providing certain types of motorist services by government contract (i.e., tow cars, service cars).
4. Develop statistical data to show how the best services available are operated and by whom.
5. Establish a way to ensure on a nationwide basis that motorists' needs for services are met with the proper response.
6. Establish guidelines for providing motorist services.

5 Uniformity in Providing Routine Motorist Services: Motorist Aid Systems in Rural Areas

Problem Statement

A uniform motorist aid system is needed that will assist in detecting stranded motorists on rural highways. This system must offer a means by which the needs of stranded motorists will be communicated and a means by which an appropriate response may be given.

Proposed Research

1. Collect data from motorists who have requested assistance via some form of motorist aid system located on a rural highway.
2. Collect data from state and county law enforcement and highway maintenance departments regarding the types and operational effectiveness of the motorist aid systems in their areas (informational signs on major highways listing services available to the motoring public, distance between informational locations, adequacy of signing pertaining to roadside information on heavily traveled rural roadways).
3. Collect data on specific information signing (Is the agency that provides gas, food, and lodging in continuous operation at least 16 hours a day, 7 days a week? Are signs that reflect seasonal information removed immediately when the service closes?).
4. Determine the motorist aid systems in use on rural highways throughout the nation, type of assistance most required (police, ambulance, fire, tow, other), and ability of responding agency to assist motorists without undue delay.
5. Determine the need for strict compliance with the Manual on Uniform Traffic Control Devices.
6. Establish whether all states should provide uniform service information signing on heavily traveled rural roadways.
7. Establish whether further research is needed in the field of motorist information signing.
8. Develop statistical data for use by agencies in improving their existing motorist informational signing.

6 Costs of Trauma Related to Highway Accidents

Problem Statement

The following information is needed at the local, state, and federal levels to provide a guide for investment in prevention, detection, notification, dispatch, and delivery of emergency medical services for victims of highway accidents: actual costs, direct and indirect, to the victim, family, business, and society in terms of lost time (productivity), treatment, recovery, and continued or aggravated physical and psychological problems.

Proposed Research

1. Develop a methodology in 2 phases for relating losses and costs in one geographical area to those in other areas.
2. In phase 1, identify the factors relating to costs, select a sampling process to determine the range in costs for accidental death and injury, identify the sources and resources for data, evaluate the parameters and methodology for the study, and prepare a report.
3. In phase 2, amend the methodology for gathering data as deemed desirable, acquire data for an area or areas, analyze the data, and prepare a report.

7 Improvement in Communication With the Motorist for Motorist Services

Problem Statement

In the past, communication with the motorist was essentially 1 way to the driver from the highway by items such as landmarks, guideposts, route numbers, information signs, and signals. Recent installations of motorist aid systems have either made 2-way communication possible or allowed the motorist (with 1-way systems) to communicate with a control center. Not all of these installations have been completely satisfactory, nor have the total motorist aid systems, including the communication subsystem, been generally acceptable to motorists. In many cases, the system was installed but did not receive the necessary attention. If communications fail, motorist aid systems become ineffective.

Proposed Research

1. Study various motorist aid communication subsystems in the context of the total motorist aid system and the total statewide highway (or transportation), police, and EMS communication network.
2. Determine whether and how the new technology and technological improvements in communications (satellites, precisely guided missiles) can be used in motorist aid systems.

Simulation and Measurement of Driving*

1 Modeling of Highway Crash-Avoidance Maneuvers

Problem Statement

Some portion of a highway crash results from an inadequate response of the driver-vehicle system during a crash-avoidance maneuver. The National Highway Traffic Safety Administration has stated its intent to specify capabilities required of the vehicle, and has efforts under way to obtain extensive empirical data on the capabilities of contemporary vehicles and driver-vehicle systems. Similarly, NHTSA has an extensive program under way to improve the capability of the driver in recognizing potentially hazardous situations to avoid undue risk.

Proposed Research

1. Analyze the frequency and nature of crashes associated with driver-vehicle dynamics.
2. Develop analytical and simulation models to reproduce typical crashes.
3. Perform sensitivity and trade-off analyses to determine the effect of vehicle-dynamic properties on the handling capability of the driver-vehicle system.

2 Measurement of Driver Work Load

Problem Statement

The driver's work load varies substantially depending on the perceptual, decision, and control functions demanded by the given driving situation and the driver's own performance criteria. Only cursory knowledge is available concerning the extent to which present vehicle and highway designs impose undue work loads on the driver. Quantitative work-load measurements that relate to the different information processing tasks required of the driver and that could be applied to a variety of driving situations would aid significantly in vehicle and highway design and driver performance studies.

Proposed Research

1. Examine subsidiary task techniques to select those most applicable to the driving situation.
2. Develop simulated driving situations that can be used to separate the major information processing aspects of the driver's task (e.g., control, search and detection, decision making).
3. Perform experiments in which the information processing demands are varied individually and in combination to determine the corresponding changes and interaction in work load.
4. Develop a driver work-load model that can be applied to field studies and eventually to highway and vehicle design criteria.

3 Driving Simulator for Research and Testing

Problem Statement

Although numerous driving simulators have been developed, no satisfactory apparatus is available in the form of either a product or a design capable of ready fabrication. If a laboratory desires to conduct research in driving performance with a simulator or if an agency wants a simulator for testing drivers, each faces a long-term development program of substantial difficulty, tremendous cost, and considerable uncertainty concerning the adequacy of the outcome. Prospective users require authoritative data for use in evaluating their apparatus needs and practical information for use in building the apparatus.

Proposed Research

1. Ascertain the state of the art in driving simulators by surveying laboratories that have working simulators and determine the driving modes that can be simulated with contemporary devices and the best equipment for each mode or purpose.
2. Synthesize a system of simulation components that can be used as "building blocks" to construct a simulator that is tailored to specific needs and that offers optimum compromise of conflicting requirements in each case.
3. Develop and fabricate suitable hardware, evaluate it by test, and redesign as necessary.
4. Prepare working plans for others to use in the form of packets containing full-sized drawings, photographs, and printed directions, material lists, and other useful information for shop and research personnel.

4 Systemization of Environment-Vehicle-Driver Interactions

Problem Statement

Highway engineers, vehicle manufacturers, and human factors researchers devote a great deal of productive effort to quantitative evaluation of performance. However, not much has been done to use control theory, modeling, simulation, and instrumental measurement for studying the overall performance and interactions of all the various factors, particularly from a safety standpoint. In this respect, highway safety today is in about the same stage as astronomy before Newton. Giant steps could be taken to improve the quality and safety of highway transportation by applying available methodology for systems analysis and synthesis. One of the most significant and valuable benefits of this research would be the universal system of verbal and mathematical nomenclature, which should be an early output from the program. This would enable scientists and engineers to better communicate their ideas, more usefully interrelate the results of their research, and more effectively apply data and conclusions. With some amplification, moreover, the mathematical model generated by the proposed research could provide an otherwise unavailable foundation for the benefit-cost analyses so greatly needed for transportation decision making.

Proposed Research

1. Collect pertinent information by literature searches and interviewing.

2. Work out a skeleton model in mathematical form for the environment-vehicle-driver system.
3. Investigate interactive situations (e.g., skid control) favorable to systematic formulation.
4. Develop for each subsystem an operational model, such simulations as are feasible, realistic test data, and quantitative comparisons with real-world events.
5. Evaluate important interdependencies of subsystem models (e.g., ramp exiting by impaired drivers).
6. Recast research results from other laboratories and incorporate them in the general model.
7. Gradually revise the general model by interactive testing and fill in the gaps with cooperative contributions from specialized facilities such as the research laboratories of car manufacturers.

5 Driving Simulator Classification and Validation

Problem Statement

Various driving simulators exist today. A simulator hierarchy needs to be established based on requirements of driver performance measurement and other requirements, and the limitations of each type of simulator need to be validated and determined by correlation with full-scale tests. The limitations of each class of simulation would then be more apparent, and the appropriate device could be selected for a given driver performance measurement purpose. Also, with a validated base line, nonexistent vehicles could readily be evaluated and better measurement techniques developed.

Proposed Research

1. Based on inherent driver response needs (rather than superficial differences such as interior designs), categorize driving measurement simulators in terms of driver training, testing, handling research, and so on.
2. Accomplish a series of tests across the hierarchy of simulators that adequately represent all simulator functions, including driver-vehicle response and performance, psychophysiological and eye-movement quantities, work-load and secondary tasks, and subjective driver opinion ratings.
3. Conduct full-scale tests and correlate results with simulator tests.
4. Quantify effects of motion cues, visual displays, and manipulator dynamics.

6 Measurement of Accident-Avoidance Maneuvering

Problem Statement

Precise data on the maneuvers that drivers employ to avoid accidents usually cannot be obtained from the accident record, and it is difficult to reconstruct accident events from delayed examination of the accident scene. Attempts to assess the influence of vehicle design and driver characteristics on accident-avoidance capability suffer from a lack of quantitative information concerning the driver's control actions and the resulting vehicle responses.

Proposed Research

1. Evaluate currently employed methods using on-board tape recorders and mobile computer simulations for on-site accident reconstruction.
2. Identify accident-avoidance situations requiring new or advanced measurement techniques.
3. Develop suitable simulation and measurement methodologies to cope with these situations.

7 Simulation for Highway Accident Analysis

Problem Statement

In accident investigation, physical facts and testimony are assembled from participants and witnesses. Analysis to establish probable cause is often difficult because the analyst is limited in his or her ability to examine the interactions and consistency of the information.

Proposed Research

1. Examine existing and projected simulation facilities in terms of requirements and form of information input to represent physical and operator variables, vehicle system characteristics to be stored in the computer information bank, extent to which vehicle system models can be generalized without significantly degrading the output, need for closed-loop capability to include operator response characteristics not available in mathematical format, cost estimate to analyze typical incidents, and assessment of the utility of simulation in accident analysis.
2. Determine the suitability and availability of facilities for accident analysis.

8 Simulation and Measurement of Driver Information Processing

Problem Statement

A driver who has a good driving record may have had many near accidents but was obviously able to perceive potential accident elements and take preventive action within the available time. At faster speeds, the driver might not have been able to take preventive actions. However, in this context fast speed does not necessarily mean high speed, but rather speed in relation to the specific driving conditions. The question is, How well can a driver process and react to accident elements of per unit of time?

Proposed Research

1. Establish a catalog of accident elements based on a review of previous research and accident reports.
2. Conduct a series of simulation experiments with drivers experiencing varying degrees of accident situation complexity (increased number of accident elements per driving situation as well as increased speed).

3. Prepare an accident element handbook that consists of accident elements listed for highway intersections, roadside environments, signing, and so on, lists accident-causing probabilities associated with each element under the specified situations, and outlines the procedures for using the accident elements and their corresponding probabilities.

9 Measurement of Driver Proficiency During Advanced Training

Problem Statement

Improvement of advanced driver training is inhibited at present by inability to measure quantitatively the status and improvement of a driver's proficiency in highway driving. Also, dynamic training simulators should be used by experienced drivers on a voluntary (e.g., defensive driving courses) and compulsory (e.g., traffic clinics) basis.

Proposed Research

1. Determine the appropriate type and schedule of instruction needed to maintain driving proficiency in research that involves driving proficiency measured during periods of time after initial instruction, repeated instruction directed toward the development of high-level skills and the maintenance of fundamental skills, instructional aids needed to provide cost-effective instruction for a wide range of tasks, and administrative problems involved in providing continuing or repeated instruction.
2. Research quantitative measurement techniques for evaluating the effect of advanced training for experienced drivers, including determinations before, during, and after periods of instruction.
3. Develop dynamic training simulators and range maneuvers to provide effective training on an economical basis for experienced drivers in need of refresher instruction.

10 Instrumented Driving Range for Research and Testing

Problem Statement

Conventional road tests used for examining applicants for driver licenses generally do not enable uniform assessment of knowledge and driving skill. If uniform test circumstances could be provided on state-operated driving ranges and performance could be recorded and analyzed automatically, testing might become more discriminating and perhaps less costly. Furthermore, such a facility would be invaluable for a variety of research investigations in driver training.

Proposed Research

1. Catalog the items of knowledge, skill maneuvers, and driving response habits that should be assessed.
2. Design a driving range containing checkpoints for the items to be assessed.
3. Develop a data collection system comprising a signal generator to be placed

in the examinee's car whereby a narrow-beam signal could be telemetered to a grid of cables buried in the roadway so that a continuous record of position versus time for the test vehicle can be recorded on a digital tape recorder.

4. Construct an abridged facility to evaluate representative elements of the test program.
5. Work out a computer program for automatically comparing an applicant's behavior at the checkpoints with norms to be determined in future tests.
6. Collect data for repeated range runs performed by a small group of drivers with varying degrees of experience or competence and analyze their test data in various ways and under different assumptions of performance criteria to establish an appropriate scoring system.
7. Validate the results of item 6 using a larger and more representative group of drivers.
8. Evaluate the cost effectiveness of the proposed system.

11 Standardized Instrument Package for Driving Performance Measurement

Problem Statement

A number of research organizations would likely use instrumented cars in their driving research programs, but do not possess the informational resources for designing the necessary apparatus. However, they probably could arrange for the equipment to be built if published designs and performance specifications were available.

Proposed Research

1. Review the literature in published journals and government reports and select the most useful variables to be measured in various categories, such as driver condition (eye movements, EKG, and GSR), control actions (steering wheel angle, accelerator position, and braking force), vehicle dynamics (forward speed and acceleration, heading and yaw, and lateral *g*), and other (clock time and voice data).
2. Develop hardware for sensing, conditioning, recording, and analyzing these data by using commercial components and consider replication cost, reliability, and adaptability to as many kinds of vehicles and types of research as practicable.
3. Field test and rework as necessary.
4. Publish engineering performance data, design characteristics, fabrication information, installation directions, hints on using the instrumentation, maintenance instructions, programs for computer analysis, and miscellaneous helpful suggestions.
5. Because of frequent technological changes, make available (at a reasonable price) design and construction details in packets containing full-sized drawings, photographs, and printed directions, material lists, and other useful information for shop and research personnel.

12 Computer-Operated Driving Simulator

Problem Statement

The integration of the driver, the vehicle, and the roadway into a compatible system is

the ultimate goal of those concerned with highway safety. Before this can be realized, however, much more research is needed to study the dynamic interaction of these elements. The accurate measurement of driver demands and reactions to both conventional driving tasks and to emergency or avoidance maneuvers is needed. This can be done only to a limited extent by present simulators or by full-scale live-driver tests. Mathematical models can accurately compute the dynamic response of automobiles. These models should be integrated with visual driver simulators that have images with which the driver can interact as he or she maneuvers the vehicle. Research is needed to determine the feasibility of developing a driving simulator that will operate in real time with digitally computed images and dynamic fidelity.

Proposed Research

1. Determine whether such a simulator can be developed with present technology and hardware or whether present aircraft or spacecraft simulators can be modified for such purposes and, if not, what the estimated lead time would be for its future development.
2. Determine the cost of the development, production, and operation of such a system and compare the benefit-cost factors of the new system and the existing methods.
3. Determine whether such a system will require government financial support and ownership, how many (if any) simulators will be needed, where they should be located, and who their potential users will be.
4. Specify the areas of application of such a system, its limitations, and the extent to which it can duplicate the actual driving environment.

13 Validation of Critical Tracking Task Simulators

Problem Statement

A fixed-base driving simulator has been proposed and constructed that uses the technique known in manual control theory as critical tracking task (CTT). This is an attractive method for quantifying the driver's work capability. The question is, How good is the correlation with real-life driving?

Proposed Research

1. Select 1 or 2 typical driving tasks.
2. Simulate one on the CTT simulator with a reasonable number of subjects to yield a range of parametric data applicable to normal driving.
3. Examine the excess work capacity of the test subjects (e.g., How well do they monitor the instrument panel and rearview mirrors?).

14 Measurement of Driving Decisions and Risk Acceptance

Problem Statement

The task of the automobile operator is widely understood to include a broad range of subtasks including a variety of cognitive processes reflected in acceptance or rejection

of risk and in the execution of particular responses to stressful driving situations. The development of quantitative indexes of risk-acceptance and decision-making functions (capable of inclusion with established measures of psychomotor performance functions and search-and-scan measures of operator performance in a general performance battery) would substantially facilitate the evaluation of drug and alcohol effects on driver performance, driver education effectiveness, and a wide variety of other critical aspects of road-user behavior.

Proposed Research

1. Identify decision-making and risk-taking elements of the driving task under normal and extreme driving conditions.
2. Estimate the frequency of exposure to the decision-making and risk-acceptance demands identified.
3. Develop quantitative indexes capable of measuring decision-making and risk-taking characteristics of drivers under normal and extreme driving conditions.
4. Relate measures of decision making and risk taking to measures of information input (search and scan) and psychomotor performance.
5. Recommend a comprehensive driver performance measurement battery that includes the quantitative assessment of decision functions that are applicable to the broadest possible range of driver evaluation uses or, alternatively, recommend separate batteries applicable to various research and driver evaluation requirements.

15 Needs of Motorists in Route Signing

Problem Statement

Suppose a driver who wants to go to Siwash approaches an interchange and is faced with a choice of I-99 North or I-99 South. He or she may not be able to determine, in a minute or so available, which compass direction is correct. On the other hand, a choice of I-99 to either Siwash or Podunk may only confuse other drivers who wish neither destination. The problem is that route labeling is not consistent and in many cases is misleading. An individual planning a trip through unfamiliar territory cannot be sure of the geometry of an interchange or how it will be marked. The consequences of this state of affairs are confusion, delay, interruptions to traffic flow, and collisions.

Proposed Research

1. Interview a substantial sample of drivers to find out how they plan trips that will take them through unfamiliar territory.
2. Determine their strategies and expectancies and the experiences they had in the past with route signing.
3. Use the results to suggest guidance in the design of signing options.
4. Prepare models for use in simulator band research where subjects who have been provided with road maps and told to go from one place to another will be faced with the various signing options (measures would include reaction time, probability of error, and subjective impressions).

16 Evaluation of Driving Simulator Displays

Problem Statement

The most common approach to evaluating real-world visual display systems for driving simulators is to measure the performance characteristics of the transmitting medium and its optical and photometric outputs and to obtain subjective judgments of the output by a group of observers. The evaluation process consists of comparing the performance characteristics and outputs to some criteria based on either broadcast television or simple physiological laboratory tests modified by the opinions of the observers. The net result is that by using present methods no consistent rating of specific visual systems for adequacy of information is possible. A method is needed for defining a performance criterion that will account for the important characteristics of simulated visual environment displayed to the driver of an automobile simulator in quantitative terms.

Proposed Research

1. Identify the classification parameters appropriate to visual scenes based on automatic pattern techniques.
2. Define the visual cues used by vehicle drivers in accomplishing the driving task.
3. Based on the above, define the real-world scenes in forms more manageable for automatic classification and recognition purposes (this will represent for the particular environment a signature that can then be analyzed for its classification properties).
4. Relate the data on the parameters mathematically in a matrix to permit prediction of the visual cue recognition from the processed information.
5. Check the validity of this matrix with new visual scenes and new subjects.

17 Alcohol Interlock Based on Driving Performance Measurement

Problem Statement

Alcohol is involved in a high proportion of the deaths, injuries, and property-damage accidents that occur on highways. Interlock systems, which would either prevent the vehicle from starting or, if overridden, would inform passersby that the system had been compromised, offer an alternative to the alcohol countermeasures currently being developed. To date, development efforts have been devoted primarily to predriving interlock systems employing representative behavioral tasks and, to a lesser extent, physiologically based sensing systems. Little effort has been devoted, however, to the use of actual driving performance measures as interlock variables.

Proposed Research

1. Review the literature that has employed driving performance measures to discriminate among various driver subgroups, including the effects of alcohol on driving performance.
2. Specify a group of candidate driving measures, ensuring that each can be measured in real time from within the experimental vehicle and without the use of external aids.
3. Examine the selected measures to determine their sensitivity to alcohol and to

the effects of confounding variables.

4. Use the results of item 3 to develop a candidate interlock device that will meet the normal interlock requirements.

Maintenance and Operations Management

1 Methods for Traffic Operations Decision Making

Problem Statement

The environment in which traffic operations decisions are made is becoming more complex. These decisions no longer are made solely on an evaluation of technical factors but are influenced directly by social, economic, and political constraints. To operate effectively within this framework requires an analysis of the manner in which decisions are made in an organization and the development of methods that can be used by management to determine implementation strategies that will be acceptable to the participants in the decision-making process.

Proposed Research

1. Analyze the decision-making process in several organizations that have traffic operation responsibilities and study the type of decisions made, the participants in the process, and the influence of the participants in the final decision.
2. Determine the extent to which nontechnical factors such as social and economic considerations, political pressures, and environmental constraints affect the evaluation of alternative plans and designs.
3. Develop the means to synthesize the nontechnical considerations and the engineering constraints within the decision-making framework.
4. Determine whether there are certain decision-making strategies used that are more successful than others in leading to successful project implementation and, if so, determine how they can be used by management in other organizations with traffic operation responsibilities.

2 Effect of Fuel Availability and Cost on the Establishment of Maintenance Priorities

Problem Statement

The fuel crisis had a profound effect on the performance of the highway maintenance function. The most obvious impact to the maintenance engineer was the unavailability of gasoline for maintenance vehicles; the result in some cases was a reduction in maintenance operations. In addition, the shortage resulted in a decrease and redistribution of highway travel and an accompanying reduction in motor fuel tax revenues. Both of these factors would have significant impacts on the establishment of long-range maintenance priorities. Projections indicate that the gasoline supply will continue to be unstable. Therefore, sound strategies for budgeting and conducting maintenance operations in this environment must be investigated.

Proposed Research

1. Determine the changes in travel patterns due to the unavailability of fuel or to increases in fuel costs and analyze the sensitivity of these patterns to levels of fuel availability and costs.
2. Analyze the impact of these changing travel patterns on the distribution and level of the maintenance provided.
3. Determine methods of organizing maintenance operations to minimize fuel consumption.

4. Develop a methodology for establishing a maintenance priority system that is responsive to varying levels of funding and changing traffic patterns.

3 Evaluation and Rating System for Highway Maintenance Operations

Problem Statement

The ability to evaluate the effectiveness of a maintenance organization in the performance of its duties is becoming increasingly important because of the intense competition for available revenues. To measure the effects of budgetary limitations and to compare performance of maintenance units within an organization are important. The problem of establishing a common measure is complex because of the great number of variables (climate, age, cross section, traffic volume, drainage) that influence the condition of a highway.

Proposed Research

1. Review and analyze maintenance rating systems now being used throughout the country.
2. Identify the most important indicators of maintenance accomplishments.
3. Establish standard levels for comparative basis.
4. Develop a method of evaluating maintenance levels that will consider the unique characteristics of a particular unit of highway (the value of the rating must justify the required investment of effort).

4 Equipment Management Procedures Applicable to Highway Maintenance Fleets

Problem Statement

Equipment management is a multimillion dollar operation in each state. Management personnel lack the time and, in some cases, the knowledge to properly design a comprehensive and effective equipment management system. A great deal of study has been done on each aspect of equipment management. Even though a large body of knowledge is available, few equipment fleets operate under the control of a cost-oriented management system. The evidence seems to indicate that a link is missing between the theory of equipment management and the practical use of existing theory, particularly as it is applied to highway maintenance activities.

Proposed Research

1. Identify replacement models that are applicable to highway fleets and determine whether a different model is needed for each machine type and whether a universal model will provide accurate results for a wide range of dissimilar machine designs.
2. Relate staff support (mechanics, welders) to the characteristics of the fleet and to an optimum replacement policy.
3. Determine the size of the fleet and type of vehicles to adequately and economically handle a given demand requirement.

4. Develop control systems to provide information with which to measure the effectiveness of past management decisions.
5. Package the management system so that implementation can be effected with a minimum number of employees.

5 Current Practices Used to Develop Maintenance Standards

Problem Statement

In September 1965 an HPR cooperative research project was initiated in Louisiana for a pioneering maintenance management study. Since that time, more than 30 state highway departments have either installed maintenance management systems or are considering installation of them. Maintenance standards play an important role in developing such systems.

Proposed Research

1. Gather information pertaining to the methods used by the various highway departments to develop (a) quality standards that establish criteria for undertaking an operation and the desired level of workmanship and end results, (b) quantity standards that establish work units required for normal maintenance operations to meet quality standards, and (c) performance (productivity) standards that establish labor and equipment hours required per work unit.
2. Assemble existing standards together in a single reference to facilitate information exchange among governmental units.

Maintenance and Operations Systems

1 Highway Maintenance Budget Modeling

Problem Statement

The management of highway maintenance and the budgeting of maintenance funds are becoming increasingly automated. This requires the quantification of various maintenance and operational requirements. Reliable models that are responsive to a variety of environmental and operational influences on different highway designs and constructions are needed to effectively implement these processes.

Proposed Research

Develop work-load models to predict the amount of maintenance and operation required for the various elements of a roadway.

2 Damages and Liabilities and Their Influence on Maintenance Programs

Problem Statement

Primarily because of scarce resources, maintenance scheduling has typically been based on a policy of responding to user complaints or of doing what is needed to protect the investment. Highway agencies know what should be done and when, but their actions are restrained by a shortage of funds. At the same time, the public is prone to hold persons in public service liable for their responsibilities. Maintenance decisions must be considered in light of the potential damage and the general liability that can result from actions or inactions.

Proposed Research

Study the extent to which damage cases have been a problem and project the trend.

3 Cost Effectiveness of Winter Maintenance

Problem Statement

In the snow-belt areas, a large percentage of the maintenance budget is directed to ice and snow removal programs. An objective method is needed to evaluate the costs of these programs in terms of their benefits to the safety, comfort, and convenience of motorists and of their potential adverse impact on the environment.

Proposed Research

Develop a methodology to determine the cost effectiveness of winter maintenance programs.

4 Estimation of Paving Service Life

Problem Statement

The relative service life and maintenance and operations costs associated with alternate pavement design and construction materials are not fully understood. This understanding, together with a standard method for predicting the future serviceability of pavements, will permit better maintenance management and serve as an aid in developing long-range estimates of financial needs. The wrong pavement decisions that are made today because of inadequate understanding of the consequences will be continually affecting tomorrow's maintenance budgets.

Proposed Research

1. Investigate the relative service life and maintenance and operating costs of alternative construction materials.
2. Develop a standard method for predicting future pavement serviceability.

5 Road Closure Criteria

Problem Statement

High traffic volumes make maintenance operations difficult, expensive, and dangerous to maintenance employees and motorists. Criteria or warrants that consider zones, partial closure, and impacts on operational cost need to be established to guide maintenance organizations in their selection from a variety of available road-closure procedures.

Proposed Research

Develop criteria for selecting a road-closure procedure based on economic and safety considerations.

6 Nighttime Maintenance Evaluation

Problem Statement

Under extreme conditions of traffic flow, nighttime maintenance operations may be necessary. Nighttime operations may reduce the level of safety and maintenance quality or may increase maintenance costs. Night maintenance should be evaluated in terms of these variables, and warrants should be developed to justify nighttime maintenance operations.

Proposed Research

Develop warrants for nighttime maintenance operations.

7 Data Processing and Data Banks

Problem Statement

Automatic and manual data processing is used throughout the maintenance organization. At local levels of government, problems generally involve the availability of analytically trained personnel, access to computers, and data interpretation. At other levels of government, the difficulties are related to uncertainty about user needs and multiplicity of objectives. Data needs fall into numerous categories. Problems arise when attempts are made to simultaneously satisfy data requirements within several of the categories. In contrast to payroll and accounting, which generally require a 100 percent data base and the highest attainable accuracy, maintenance control and evaluation may use less than a 100 percent data base and lower accuracy. How much less should be the subject of research. Two specific questions need to be answered: Under what circumstances is sampling acceptable or preferable? Under what circumstances is sampling economically advantageous? Equal in importance to the question of sampling are questions of reporting categories and units that are not based on accounting data and of using standardized units.

Proposed Research

1. Determine applicability of sampling.
2. Evaluate whether reporting categories and units should be related to tasks rather than to accounting breakdowns.
3. Evaluate the use of standardized reporting categories and units (already under review).
4. Determine data base retention requirements.
5. Examine review and control procedures on maintenance information systems.
6. Evaluate uses (and potential uses) of maintenance information systems in operation.
7. Determine data base accuracy requirements and control.

Maintenance and Operations Personnel

1 Training Costs and Effectiveness

Problem Statement

Although training of maintenance employees is desirable and results in increased productivity and employee job satisfaction, quantitative information is lacking on costs and effectiveness of such training.

Proposed Research

1. Undertake a survey of the costs attributed to the formal training of maintenance and operations personnel and the effectiveness of training materials to include training methods, use of pretests and posttests, annual number of hours of training per trainee, and measures of effectiveness.
2. Collect copies of lecture notes, scripts, books, or handouts used during the training.
3. Collect, tabulate, and analyze the costs of training maintenance and operations personnel and indicate the relative effectiveness of the methods being used for training of maintenance and operations personnel.
4. Establish and publish budgetary guidelines for agencies interested in the development and implementation of formal training programs.

2 Management Support

Problem Statement

Installing new management systems is dependent on successful communication among all levels of supervision in the maintenance organization. Failure to successfully convey management intentions to lower supervisory personnel has resulted in less than complete success for some performance budgeting systems.

Proposed Research

1. Survey the type and content of communication from top management through first-line supervision.
2. Review current literature regarding approaches to the status of middle and first-line supervisors.
3. Identify the most effective ways of communicating job roles, responsibilities, and status to middle and first-line supervisors.

3 Personnel Selection and Placement

Problem Statement

Information on the methods and criteria being used to screen, select, and place maintenance field employees is lacking, but subjective opinion undoubtedly plays a prominent role in the selection process. A need exists to identify those methods and criteria that

could be used to more effectively select and place employees.

Proposed Research

1. Survey and review the criteria used to screen, select, and place maintenance field employees.
2. Recommend improvements in the current procedures and criteria.

Traffic Law Enforcement

1 Traffic Police Assignment

Problem Statement

Several attempts have been made to develop a formula for the most effective assignment of traffic officers on a highway system. No one formula will answer all the needs for service on highways that have varying traffic volumes and varying degrees of availability of other emergency services and communication. A study is needed to develop a formula for traffic patrol assignment and to establish a minimum effective or acceptable level of performance. Such a research effort would include but not be limited to the following work-load factors: traffic volume, vehicle population, and pedestrian traffic volumes. Also considered, both together with and separate from these, should be geography or topography and its effect on personnel assignment in normal or high traffic areas and its effect on response capability in areas where a formula based on traffic volumes alone (in low traffic area) would not justify a significant number of personnel.

Proposed Research

1. Determine the optimum level of hazardous moving traffic violations for various conditions (urban, suburban, rural).
2. Identify and measure the effect of the enforcement of nonhazardous traffic violations and establish performance levels.
3. Determine the optimal level of police accident investigation and its relation to the allocation of enforcement resources.
4. Identify the relation between the minimal and optimal traffic law enforcement and the total manpower requirements for the police traffic service function.

2 Intent as a Factor in Traffic Law Violations

Problem Statement

In most non-accident-producing traffic violations, the intentional nature of the violation is not considered an element of the offense. However, the degree to which violations are committed with willful disregard of the prohibitions would be of considerable value in planning police enforcement programs and educational programs by the courts, schools, and police. This relation between intent and the violation of traffic laws has not yet been adequately determined.

Proposed Research

1. Determine what proportion of each type of traffic violation is committed in ignorance of the law, unintentionally (because of a great number of possible factors), and intentionally.
2. Develop a profile on the intentional violator, a taxonomy of the various traffic violations, and their probability for intentional violation.

3 Accident and Violation Experiences of Traffic Law Offenders

Problem Statement

Apprehension and punishment or corrective action has been assumed to cause changes in the driving habits of traffic law violators, but this assumption has not been scientifically tested. No study compares violators who have been apprehended with those who have not.

Proposed Research

Evaluate and compare the changes in violation and accident experiences of persons committing hazardous traffic law violations who are (a) prosecuted without on-the-spot apprehension by the police (detection without apprehension by the use of a continuous surveillance technique), (b) apprehended and charged by police who observe the violation, and (c) neither apprehended nor charged with their offenses (detection and prosecution by the use of an automatic continuous surveillance device).

4 Use of Nonsworn Personnel

Problem Statement

The constantly increasing demand for police services and the spiraling cost of recruiting, training, and equipping regular uniformed police officers have necessitated the search for alternative methods of performing certain routine tasks.

Proposed Research

1. Determine the extent to which civilian personnel can be used in specific police traffic service tasks.
2. Measure the economic feasibility of, public reaction to, and quality of performance of civilian or parapolice in accident investigation, traffic direction and control, and traffic law enforcement.

5 Optimum Use of Speed-Measuring Devices

Problem Statement

Several models and types of radar, speed computers, and continuous surveillance speed-detection devices are currently being marketed for use by law enforcement agencies. Each of the devices has particular utility for specific geographic, road type, traffic volume, and other factors.

Proposed Research

1. Evaluate the application of the available speed-measuring devices under circumstances approximating conditions encountered by a representative cross section of

state, county, and municipal law enforcement agencies.
2. Document the specific advantages and weaknesses of the speed-measuring equipment now available.

6 Automatic Vehicle Identification and Monitoring Systems to Aid Police Traffic Services

Problem Statement

Recent technological advances in automatic vehicle identification and monitoring systems hold the promise for improving the deterrent effect of traffic law enforcement by maximizing the probability of detection and apprehension. In addition, the continuous surveillance capability of this technology should have application in detecting and reporting of traffic accidents. The potential use of this type of equipment has yet to be thoroughly explored.

Proposed Research

Determine the applicability of proposed automatic vehicle identification and monitoring systems for police traffic services purposes.

7 Hitchhiking as a Factor in Traffic Accidents

Problem Statement

Some 20 percent of this country's annual traffic accident fatalities are pedestrians. The relation between hitchhiking and motor vehicle-pedestrian traffic accidents has not been clearly quantified.

Proposed Research

1. Determine the involvement of hitchhikers in motor vehicle-pedestrian accidents.
2. Examine the effectiveness of law enforcement techniques to reduce the hazard created by persons soliciting rides on or near the roadway.

8 Drinking Drivers and Pedestrians

Problem Statement

Traditionally, safety officials have attempted to curb the drinking driver by imposing harsh criminal penalties and administrative sanctions. Sometimes these penalties call for mandatory incarceration or mandatory loss of license for extended periods. Until recently, inebriated pedestrians were treated in a similar fashion. In many jurisdictions, alcoholics are not incarcerated but are treated medically or hospitalized.

Proposed Research

1. Determine the most effective way to identify, adjudicate, and rehabilitate drinking drivers and pedestrians.
2. Develop a predictive profile to identify the problem drinking driver.
3. Determine how to administratively adjudicate such cases and channel such persons into rehabilitation programs while, at the same time, preserving their licenses to drive under restricted conditions, if necessary.
4. Determine the effect of removing mandatory criminal and administrative penalties.

Roadside Maintenance

1 Maintaining Cover Material on Seeded Areas

Problem Statement

When the grass cover dies on roadside slopes, serious erosion occurs. Although fertilization would solve most of these problems, increasing roadside areas required by new design standards make it unlikely that funds can be found for maintenance fertilization programs. Hybridization and selection of grasses and legumes by agronomists have been oriented toward forage grass. Dwarf species that have low fertility requirements and can adapt to the highway environment have received little attention.

Proposed Research

Develop varieties of grass that require little or no maintenance fertilization yet have vitality, tolerance, seedling vigor, and low growth to match a wide variety of roadside demands in different regions of the country.

2 Salt-Tolerant Grass

Problem Statement

A grass species or variety is needed that is capable of growing on soils where the soluble salt concentrations exceed 20,000 ppm. The need is greatest at this time in or near population centers and large metropolitan areas, but a need will be created in the future as salts are accumulated along all rural Interstate highways and many primary highways. Establishment of suitable grass cover will reduce erosion, stop siltation of drainage flow lines, and contribute to cleaner groundwater.

Proposed Research

1. Identify and develop a variety of grass with a high tolerance to salt.
2. Provide specific techniques for seeding or sodding this new variety on highway roadsides.

3 Economic Value of Roadside Maintenance

Problem Statement

In the development of budgets and priorities, provision of roadside aesthetics has historically been relegated to a minor and insignificant role basically because of the inability of the administrator to justify aesthetics in cost-benefit terms. In the current national effort to improve the roadside environment, grading, judicious mowing and herbicide programs, acquisition of scenic strips and adequate rights-of-way to effect buffer strips, strict utility control within the rights-of-way, and billboard and junkyard controls are all part of roadside activities that must be evaluated by the administrator during budget preparation if roadside programs are to be adequately financed to meet the public's demand for environmental improvement.

Proposed Research

1. List by priority the various roadside items that influence roadside aesthetics.
2. Evaluate the costs and benefits for each item.
3. Establish a coefficient for each item as it relates to the maintenance expenditure per lane mile.
4. Give proper weighted values to the numerous maintenance costs involved, considering the need for improving the roadside environment, so that administrators can prepare realistic budgets to accomplish aesthetic objectives.

4 Roadside Maintenance by Contract

Problem Statement

Lack of personnel and need for specialized equipment for proper maintenance of roadsides are becoming noticeable as the highway system ages. Prior practices cannot continue as the Interstate Highway System nears completion and more emphasis is placed on services, such as sanitary facilities in safety rest areas.

Proposed Research

Develop better and more economical methods of maintaining roadsides by contract, including the performance type of contract.

Maintenance of Traffic Control Devices

1 Maintenance-Management Standards for Traffic Control Signals

Problem Statement

Establishment and management of an effective and efficient traffic signal maintenance program are primary responsibilities of both state and municipal traffic engineers. Lamp burnouts and other signal malfunctions can create extreme hazards to motorists and cause unnecessary delay and traffic congestion. Little information is available in the literature to assist the engineer in this task, and most signal maintenance programs are based on local experience. As an increasing number of political subdivisions lose their sovereign immunity, to establish uniform standards and procedures for signal maintenance is even more important.

Proposed Research

1. Develop preventive maintenance standards and procedures that take into account equipment type, equipment density, and total area to be serviced.
2. Develop emergency maintenance standards and procedures and describe the malfunction detection system and the communication system for handling malfunction reports.
3. Describe the personnel and equipment needed to implement these preventive and emergency maintenance procedures.

2 Optimum Pavement Marking Program for Governmental Agencies

Problem Statement

Most governmental agencies faced with the task of maintaining the pavement marking systems on public roadways within their jurisdiction are currently meeting this responsibility through the operation of a pavement striping program consisting of both force-account and contract striping. However, the effectiveness of each method and the economic trade-offs between the 2 methods are not known at this time.

Proposed Research

1. Determine the most effective and efficient pavement marking maintenance program for governmental jurisdictions responsible for urban and rural roadways with varying levels of traffic density.
2. Develop economic models that consist of a variable combination of maintenance accomplished by the force-account and the contract method; that minimize the cost of the maintenance program by optimizing the combination of the 2 work methods; and that include for each method (a) all costs for personnel, equipment, and materials, (b) costs for traffic control during maintenance operation, (c) frequency of maintenance, and (d) type of pavement marking material, given specific levels of wear.
3. Consider pavement marking materials and maintenance equipment that are currently in use by or available to governmental agencies.

3 Improved Maintenance Process for Highway Sign Lighting Systems

Problem Statement

The current use of fluorescent lighting to illuminate overhead signs requires frequent maintenance because of the short lamp life of the fluorescent fixture. The performance of this maintenance task generally requires the blockage of one or more lanes on an expressway and results in hazardous working conditions for maintenance personnel and in increased maintenance costs.

Proposed Research

1. Inventory the procedures currently being used to maintain the major types of highway sign lighting systems.
2. Develop the optimum maintenance procedure, including a description of personnel and equipment for maintaining fluorescent tube, mercury vapor, or any other lighting specifically designed for highway signs.
3. Describe the safety benefits and the economic costs of performing the maintenance task at night versus day for various combinations of volume, sign density, and number of lanes for each lighting system described.
4. Limit the research to maintenance aspects of sign lighting fixtures, rather than optical qualities of the fixture, and to design changes to improve maintainability.

4 Traffic-Actuated Signal Control Equipment

Problem Statement

Under the Traffic Operations Program for Increasing Capacity and Safety many political jurisdictions are installing traffic-actuated signal systems. There are 2 types of circuitry used in the design of traffic-actuated signals: electronic controllers that use electron tubes and solid-state controllers that use semiconductor devices exclusively. The initial cost of the equipment is but one factor that must be considered in the choice of which one to use. The continuing maintenance requirements of each type and the initial cost must be considered. However, the continuing maintenance requirements of both types of equipment are normally not fully understood by the traffic engineer who must make the selection.

Proposed Research

1. Determine the nature and frequency of maintenance required for both types of control equipment.
2. Determine the relation between these maintenance requirements and the age of the equipment, taking into account other factors such as environment, which may influence the maintenance requirements.
3. Describe the skills, training, or knowledge required of the personnel performing the maintenance on both types of control equipment.
4. Describe the equipment required to properly perform the maintenance.
5. Convert these maintenance requirements into cost requirements, including the cost of retaining personnel.
6. Determine the relation between these maintenance cost requirements and the number of traffic signal controllers within the signal system being maintained.

Parking and Terminals

1 Operational Effects of Curb Parking on Traffic Accidents at Urban Intersections

Problem Statement

View obstruction due to curb parking at 2-way-stop controlled intersections poses a serious traffic accident problem in many urban areas. At the present time, the relationship of the no-parking distance on safety is not known, and controversy exists as to the appropriate no-parking zones and needed sight distances at urban intersections. For example, the Manual on Uniform Traffic Control Devices for Streets and Highways suggests a minimum 20-ft (6-m) no-parking zone at nonsignalized intersections with various turning radii. Thus, the minimum standard specified in the manual is not always the safest prohibition distance required for needed sight distances under various design radii and speeds. A comprehensive study is needed to investigate view obstruction and curb parking effects on accident occurrence at intersections.

Proposed Research

1. Determine the effectiveness of parking-prohibition distance on traffic accidents at nonsignalized urban intersections.
2. Determine the effects of no-parking zones on traffic safety and sight distances at intersections.
3. Determine the optimum safe no-parking distance for intersections with various radii and speeds.
4. Provide comprehensive guidelines for traffic and highway engineers in selecting the safest no-parking distances.

Operational Effects of Geometrics*

Problem statements from the Committee on Operational Effects of Geometrics were developed in 2 groups over a period of time. Statements 1 through 22 were developed first and have 3 priority groupings: Statements 1 through 4 have priority A, statements 5 through 9 have priority B, and statements 10 through 22 have priority C. Statements 23 through 30 were most recently developed and are not in any order of priority.

1 Safety Benefits of Higher Level Design Standards

Problem Statement

Since the enactment of the Highway Safety Act of 1966, many state highway departments have revised their design standards to require construction of wide shoulders, wide medians, and gently sloping border areas beyond the shoulders. In addition, new safety criteria require the use of guardrail barriers placed in front of immovable obstructions that existed in these areas. These improvements are being made to assist the driver of the out-of-control vehicle that leaves the travel way to bring the vehicle to a stop with a minimum of damage or injury or to safely reenter the traffic stream. Many miles of these improved highways, both 2-lane and multilane, are open to traffic. A direct comparison should now be made of the relative safety between the new and the old designs through analysis of accidents or other means so that the effectiveness of these new design features can be determined. Studies should include both low- and high-volume highways in both urban and rural areas.

Proposed Research

1. Compare the accident rates (and severity) on highways constructed (or upgraded) to meet new safety standards with those on highways that previously met accepted design criteria prior to issuance of safety standards but are now considered substandard (so far as possible, characteristics such as design class, traffic volumes, and terrain should be similar for both groups of highways being evaluated).
2. Compare the relative safety of the design of subelements, such as guardrail, shoulder width, flatter slopes, and clear area width, for both groups of highways.
3. Include cost-effectiveness analyses to measure the benefit received from greater cost required to provide a higher level of safety.

2 Effect of Illumination on Traffic Operations and Safety

Problem Statement

Nighttime highway accident rates tend to be significantly greater than daytime rates, and conventional roads tend to experience significantly higher accident rates than do freeways. In addition, roadways with more uniform and intense roadway lighting tend to experience lower highway accident rates and less severity than those that are not so lighted. Many factors affect the nighttime driving task. Although the human eye is adaptable to a wide range of lighting intensities, the rate at which it can adapt is slow. In addition, the driving task is affected by environmental factors, particularly roadway reflectance, reflective signs, markings and delineators, and the type of front, rear, and side vehicle lighting systems.

Before and after studies have been a useful technique in assessing the effectiveness of roadway lighting programs. Current state-of-the-art knowledge suggests general relations between intensity of illumination and accident experience. A comparison of nighttime and daylight accident experiences showed that no street lighting produces 50 percent more accidents and poor street lighting produces 30 percent more. A 7-year-old California study concluded that continuous low-intensity illumination ranging from 0.20 to 0.35 ft-c (2.15 to 3.77 lm/m^2) is not effective in reducing night accidents. Currently there are 2 approaches to roadway lighting practices: silhouette lighting and reverse silhouette lighting. These practices are related to the perceived cost effectiveness of each approach. Despite the increasing trend to roadway lighting and the recognition of these general trends in safety experience, the relations among highway safety, traffic operations, and roadway lighting practices are not well understood. Little research has been performed for conventional roads relating highway lighting to driver-vehicle performance while isolating and controlling environmental variables such as roadway reflectance and geometry.

Proposed Research

1. Determine the environmental factors that affect night visibility and their relations to the driving tasks.
2. Determine the effect of the uniformity and intensity of roadway illumination on operating and safety characteristics such as speed, lateral placement, headways, and accident experience.

3 Effects of Weather on Accidents, Driver Behavior, and Traffic Operations

Problem Statement

Only limited information is available on the effects of weather such as rain, snow, hail, ice, fog, thunder, lightning, wind, heat, cold, and humidity on accidents, driver behavior, and traffic operations. These phenomena also affect driver visibility and vehicle handling.

Proposed Research

1. Investigate the effects of weather conditions on accidents and accident rates; driver judgments of speeds, distances, and closing rates; vehicle handling; and traffic parameters such as gap acceptance, speeds and speed variances, headway, lane position, volume, and capacity.
2. Relate these factors to cross section and alignment, number of lanes, type of road, type of maneuver, light condition, pavement condition, illumination, delineation treatment, vehicle type, vehicle make and age, driver age and sex, and driver experience.
3. Analyze these factors through observational and experimental studies.
4. Analyze accident reports to determine the effect of weather in accident causation in a variety of study sites and develop improved accident reporting systems that provide for consideration of weather.
5. Determine significant combinations of driver, vehicle, weather, and road characteristics that influence accidents and traffic operations.
6. Assess possible roadway, vehicle, and driver remedial measures to reduce the effects of weather on accidents and traffic operations.

4 Communication With Drivers

Problem Statement

Drivers need to be made aware of regulatory, directional, and roadway condition information in a nondistracting, completely adequate manner.

Proposed Research

1. Determine what information the driver must have to negotiate interchange areas, roadways with adjacent commercial usage, construction areas, and emergency situations.
2. Determine the methods of communication available for this purpose by visible, audible, or other means.
3. Determine driver reaction and subsequent vehicle operation because of communication, particularly reactions to signals, time required to comprehend any signal, depth of absorption in signal comprehension, and attention diverted from vehicle operation.

5 Visibility Considerations of Highway Medians

Problem Statement

To maintain efficient and safe traffic conditions, vehicle operators must recognize the physical alignment of the highway median at the earliest possible moment. A median can become a hazard unless it is plainly visible. A satisfactory level of median visibility should therefore be considered as an essential safety feature of the highway facility. Effective measures of improving median visibility, particularly at night, have not been established. Specifications for median visibility under various situations are urgently needed and should be adopted uniformly throughout the nation. A study should be conducted to serve as an aid in determining the most advisable method of median delineation under a given set of roadway conditions. To be incorporated into both existing facilities and for future facilities, the determined methods must be used correctly to avoid all possible traffic accidents due to inadequate median visibility.

Proposed Research

1. Identify the problem of median visibility on multilane, divided highways.
2. Establish criteria for the selection of materials and techniques for median visibility delineation.
3. Determine what can be done to ensure median visibility at all times and under all visibility conditions.

6 Barriers on Narrow Medians

Problem Statement

Median barriers are installed to make highways safer by reducing accident severity.

Properly designed installations accomplish this goal by preventing out-of-control vehicles from entering the opposing stream of traffic and by redirecting out-of-control vehicles to a direction parallel to the flow of traffic. Even though the median barrier is a recognized safety device, is too much of the capacity of the facility sacrificed to provide this additional safety? What effect does a rigid median barrier placed in a narrow median (approximately 3 ft or 1 m in width) have on the capacity of the roadway? We know that objects placed closer than 6 ft (1.8 m) to the edge of the pavement have a definite restricting effect on the capacity of the adjacent lane. However, a continuous restriction, such as a barrier guardrail, is probably less restrictive than a series of separate obstacles.

Proposed Research

Determine the condition at which median barriers must be provided in narrow medians, considering traffic volume, speeds, percentage of turns, accident experience, and overall capacity.

7 Driver Behavior Studies

Problem Statement

Generally, the older a road facility is, the higher the level of regulation and control imposed on the driver will be. The building of newer and better facilities increases the inventory of obsolete designs that have slower traffic movement and frictions caused by circulating traffic, parking and unparking, truck loading, dense signalization and channelization—all of which affect motorists by restricting their freedom. Reactions to these higher and higher levels of control are quite varied. Most drivers will accept the need for such apparent substitution of control for design, because obviously everything cannot be rebuilt every time important progress is made in geometric design. However, a sizable number of drivers place their personal interests first and violate the regulations that make older designs workable. Research should constantly be directed toward testing driver reactions to various controls (and to progressive levels of control) to develop information describing the best possible way (and rate) of implementing these controls and of providing interface connections between facilities of various vintages of design to attain the highest level of understanding and acceptance by road users. A wealth of information on the characteristics and distribution of people according to perceptual, motivational, and attitudinal profiles is rapidly becoming available. None of this information is being brought to bear on the problems created by the rapidly changing design, regulation, and control of facilities. If properly applied, such information could greatly enhance the beneficial operational effects of geometric design, traffic regulation, and traffic enforcement and control. People are all different; and traffic engineers have probably addressed a type of average driver who does not actually exist.

Proposed Research

1. Develop design techniques and public information programs that recognize the overriding significance of the cross-sectional design element in communicating to drivers different driving tasks, tolerances, and alternatives, notwithstanding other means of communication such as signs, signals, markings, delineators, and barricades, which also do not necessarily serve the different types of drivers in the same ways.

2. Determine how much information a driver can handle.
3. Define the driver for which roadways and traffic control devices should be designed.
4. Quantify the informational band currently placed on drivers under various environmental, roadside, and traffic flow conditions.

8 Application of Curved Roadway Cross Sections to Freeway Entrance and Exit Ramps

Problem Statement

Normal design for the cross-sectional curvature of freeway entrance and exit ramps is a flat lane that is either level or superelevated and that is incorporated usually in a horizontal curve. Since construction practice limits superelevation to about 10 percent, large areas of land are necessary and only one neutral design speed is used. The neutral speed, wherein the vehicle has no centripetal side force, is of course a function of the radius and pavement superelevation. Freeway entrance and exit ramps have become the key design variable in at least 4 aspects of highway construction: (a) the determining factor of traffic operation in urban applications as increasing efforts are made toward effective 2-lane designs; (b) a major land use requirement, particularly in complex intersections of major highways; (c) a significant construction cost variable, estimated to account for as much as 10 percent of rural and 50 percent of urban paving areas; and (d) a prime accident location or causal factor, for vehicles exit at greater than neutral speeds or attempt to merge at inappropriate entrance speeds. Privately owned automobile test tracks use curved roadway cross sections, varying the superelevation across the roadway and accommodating a spectrum of vehicles at neutral speeds, as a function of their lateral location. Research is needed that considers primarily single-lane ramp designs that diverge to wider curve cross sections, but the capability of multilane ramps should be explored on a secondary basis. Projection of the new designs should be based on contemporary data and traffic simulation models.

Proposed Research

1. Optimize entrance and exit geometrics for traffic flow, land area, and safety, adding curved roadway cross sections as a design variable.
2. Develop design, staking, and construction methods for more sophisticated transitions and multilane applications of the curved cross sections.
3. Investigate existing construction equipment and recommend efficient techniques and equipment to minimize the construction cost and time for such curved cross sections.

9 Skid Resistance Range of Bituminous Pavements at Different Speeds

Problem Statement

States employ different standard mixes for bituminous pavements for primary highways.

Because of economy, pavements are commonly made of materials locally available in the regions. To date, skid resistance inventory tests have indicated that (a) pavements of the same basic design, when built of different regional materials, result in different ranges of skid resistance; (b) in any one region, pavements of the same basic design do not have the same skid resistance, but rather result in generally a rather well-defined range of skid resistance that differs from region to region; (c) some combinations of materials appear to wear and polish more than others; and (d) skid resistance of a bituminous pavement appears to vary with seasonal changes. There is a general movement toward the selection of minimum desired levels of skid resistance on pavements of primary highways with selected posted speed limits. The designation of these desired levels makes it essential that highway and transportation departments anticipate what the skid resistance of a pavement is likely to be prior to its construction and what it is likely to be after sustaining various amounts of traffic. In the proposed research, objectives can be achieved by skid testing, with a standard 2-wheeled trailer, a large number of selected pavements throughout the regions of each state and correlating these results with construction data and traffic history. Maximum advantage should be taken of skid resistance test results already available and of the results of HPR research studies on skid resistance and wear and polishing of aggregates.

Proposed Research

1. Determine what range of skid resistance, at selected posted highway speeds, is likely to result from the construction of a bituminous pavement of specific design from materials locally available in each region of each state.
2. Determine which of these combinations of materials is likely to polish and to what extent the skid resistance will be degraded under specified volumes of traffic.
3. Define the seasonal change likely to be experienced in skid resistance of bituminous pavements in the various regions of each state.

10 Median Barrier Design for Illumination

Problem Statement

Most types of median barrier fences in use perform well and have both good and bad features. They vary from rigid concrete barriers to deflecting fence and cable installations. Recent developments indicate that in the future most highway illumination will be mounted on poles in the median. This presents a problem particularly with the deflecting median barrier, for the illumination pole placed in the median will probably not be designed with a breakaway base because of the problems associated with having a pole knocked down into a traffic lane. Illumination poles have been mounted on concrete barriers, but the state of the art here is not clearly established.

Proposed Research

1. Review the possible combinations of median barrier design and illumination pole mounting.
2. Determine an optimum arrangement for various median widths up to about 40 ft (12 m).

11 Horizontal and Vertical Alignment Design

Problem Statement

Calculation methods for road alignments and particularly for curves have been established for many years based, at least to some degree, on quantitative riding comfort and vibration limits. Although the dynamic aspects of highway geometry are generally known, inadequate information is available for optimizing road design with respect to human comfort.

Proposed Research

1. Determine the interaction between vehicle dynamics and road geometry as mediated by driver behavior and give particular attention to the ability of drivers to negotiate curves as influenced by transition geometry and vehicle dynamics, specifically, (a) determining human perception thresholds for lateral, longitudinal, and vertical translational motions and yaw, pitch, and roll motions and (b) determining the sensitivity threshold of the many complex combinations of these individual motions.
2. Examine geometrics including curvature and superelevation on high-speed turning roadways (as at major interchanges), cross-sectional design on freeways having 6 or more lanes and in passing zones on 2-lane highways, and vertical curvature at railroad-highway grade crossings.
3. Establish levels of tolerance between the driver and geometric standards pertaining to radius of vertical curvature, length of vertical curvature, and sight distance.
4. Establish quantitative criteria for properly combining horizontal and vertical alignment design to avoid alignment losses, inflections, and curvature changes in humps that cause adverse anxiety reflexes by drivers.

12 Effects of Visual Influences of Human-Engineered Objects on Traffic Operations

Problem Statement

To know whether traffic operations are affected by the visual influences of human-engineered objects that are placed off the highway right-of-way would be valuable as an aid in future land use planning. These objects would include buildings or structures that reflect glare or cast shadows, smokestacks that emit smoke across bridges, and other roadways.

Proposed Research

1. Observe driver behavior under specific situations selected for study.
2. Compare these findings to driver behavior under otherwise normal circumstances.

13 Effect of Climatic Phenomena on Traffic Operation

Problem Statement

There is some evidence that driver reactions are affected by climatic phenomena such as thunder, lightning, electrostatic fields, extreme high or low pressure areas, and other miscellaneous natural happenings. The extent and nature of the effect have not, however, been adequately measured.

Proposed Research

1. Determine the extent of the problem.
2. Study the effects of any given natural phenomena to determine methods of control or elimination of the effect.

14 Relation of Air Pollution to Physical and Operational Variables

Problem Statement

Although there are many contributors to air pollution, the single greatest contributor is the motor vehicle powered by an internal combustion engine. The air pollution problem is especially critical in large urban areas where the density of motor vehicles is high. Efforts are being made to improve detection and control of air pollution and to develop engines that will operate with levels of exhaust emission within limits determined to be acceptable. Regardless of improvements made, however, traffic in the foreseeable future will be composed of a mix of vehicles with engines producing varying amounts of air pollution. Air pollution will be greater when traffic congestion and traffic density increase. A method is needed to quantify this relation of air pollution to operational characteristics for various types of facilities and mixes of motor vehicles.

Proposed Research

1. Determine the relation between the geometrical and operational characteristics of various classes of roadways and the level of air pollution emitted from motor vehicles.
2. Evaluate or develop detection devices or systems to measure the amount of pollution a vehicle is emitting at operating speeds.
3. Study the relation of a city's altitude, climate, and geographical location to air pollution so that planners, weather forecasters, and others can more accurately predict needs and methods of combating air pollution.

15 Air Pollution Criteria

Problem Statement

There is no doubt that transportation facilities cause air pollution, but there is considerable doubt as to how much pollution is attributable to any given facility, at any

particular time, and under any given weather condition and ambient air pollution level. Some measurement devices, weather data, and traffic volume data exist, but no real criteria or even guidelines exist to predict air condition contours adequately in the vicinity of a transportation facility. No real criteria exist concerning the amount of air pollution that is tolerable or acceptable to those adjacent to a transportation facility. The planner and the designer do not know what to use for criteria in determining the impact on the environment. Elements such as smoke and diesel odors are undesirable from a comfort standpoint, but they are short-lived, short-ranged, and reportedly nontoxic. Carbon monoxide on the other hand is odorless, tasteless, and lethal. The concentrations necessary to affect health, however, are normally not created on open right-of-way situations.

Proposed Research

Determine air pollution criteria similar to the noise level criteria contained in NCHRP Report 117 that will satisfy the driver, the adjacent population, and the general air condition and that give ranges of pollution by type for a proposed transportation facility.

16 Noise Abatement Materials

Problem Statement

The highway itself is noiseless, but traffic on the highway is noisy. Noise is created by the powerplant of the vehicles that use the highway, by the bodies of the vehicles, and by the passage of the vehicles over the pavement. One method of controlling highway noise is through the use of sound-absorptive materials to screen noise from drivers and from those adjacent to the highway. Sound attenuating materials for tunnel lining and for retaining wall coatings would aid driver comfort. Sound absorptive screens scattered throughout the periphery of the highway might greatly reduce noise pollution to those who are near the highway.

Proposed Research

1. Determine the effect of sound-absorptive, attenuating, and deflecting materials on noise abatement.
2. Determine the effect of placement and use of sound-abatement materials.

17 Influence of Microvertical Alignment on Vehicle Control

Problem Statement

A number of variables have been and are being investigated for dealing with the problem of out-of-control vehicles, particularly those on wet pavement. The pavement-tire relation is being studied from the standpoint of friction with varying amounts of moisture present, and situations in which hydroplaning might occur are receiving considerable attention. Most of these efforts and most current design criteria consider the weight of the vehicle to be an active force against the pavement. This is undoubtedly true during most periods of time, but the microvertical alignment (faulted

pavement joints, fill settlement, bridge and culvert settlement, feather-edged surfacing termini) or irregularities in the pavement surface can and do produce vertical force components in the motion of the vehicle that can result in little or no part of the weight of the vehicle being transmitted through any particular wheel of the vehicle to the pavement for varying lengths of time. Since nearly all design criteria and all procedures for determining skid resistance consider the weight of the vehicle to be resting on the pavement, it is entirely possible that these criteria and procedures are not applicable under certain conditions of pavement irregularity. Research devoted to the weighing of vehicles in motion has clearly shown that we can expect the dynamic load on the tires of moving vehicles to vary by as much as 100 percent of the static load; 0 load on the tires of moving vehicles has been recorded over distances as great as 14 ft (4 m).

Proposed Research

1. Measure the joint influence of microvertical alignment with horizontal alignment or pavement crown or both on adverse vehicle behavior (incidents and accidents) that cannot be attributed solely to other variables (vehicle handling characteristics, driver response, degree of curve, ambient pavement friction, width of shoulder, roadway delineation, traffic conflicts).
2. Measure weight components against the pavement at many microvertical irregularities.
3. Collect accident data at such locations.
4. Collect by photographic means vehicle movements at such locations.
5. Correlate the data collected.

18 Effect of Shadows Cast by Roadside Features on Traffic Operations

Problem Statement

During the past few years, accident analysis review teams have concluded that shadows cast by roadside features on the travel lanes of rural high-speed highways have been a significant factor in the cause of accidents. Motorists appear to be reluctant to drive over these shadows, resulting in hesitation, distraction, and often rapid change in the vehicle travel path. Obviously, all shadows cannot be eliminated from the travel lanes, but a better understanding of driver reaction to various shadow patterns would provide safety engineers with valuable data to support the clear roadside programs. Research on vehicle tracking, running speed, and driver reaction in maneuvering through a shaded area during daytime operation and in lighted sections at night is worthy of consideration. Shadows are known to produce unexpected patches of ice and frost at certain seasons of the year because of delayed diurnal insolation. The relative importance of this effect as an accident causative factor also needs to be determined.

Proposed Research

1. Study the effect that shadows cast on road surfaces have on motorists approaching and driving over such shadows.
2. Study the effect that shadows have on road surfaces with regard to ice formation where shadows are cast.

19 Noise Pollution

Problem Statement

What is noise pollution? What effect does transportation noise have on people? How and when do we measure noise levels? The standardization of measurement and recording of noise levels for transportation should be accomplished. The measurement of peak-hour traffic noise for 15 minutes in one state may be compared with measurements for 5 minutes at 11:00 p.m. in another state and with measurements by a random spot reading in another state.

Proposed Research

1. Analyze and evaluate the various opportunities and methods for measuring transportation noise.
2. Develop standardized guidelines.

20 Operational Limitations on the Maximum Number of Freeway Lanes in Urban Areas

Problem Statement

In highway planning and design practice in large urban areas, the maximum number of contiguous through lanes on a freeway roadway has generally been limited to 4, and demands exceeding its capacity have been provided for through the careful development of a transportation system based on spacing requirements related to economic considerations and density of development. The construction of carefully developed urban transportation systems has tended to lag behind current needs because of either insufficient capital funding or public opposition to specific urban routes. As a consequence of these delays, traffic demands on the existing system of freeways have caused operational saturation requiring remedial measures such as traffic surveillance and ramp metering or conversion of continuous shoulders to use as traffic lanes. Should such delay to the construction of new and much needed facilities continue into the future, and present trends seem to indicate this will be the case, to plan, design, and construct freeways with greater capacity than that which would be required when a completed system is available may be cost effective. The addition of a lane could produce a 20 or 25 percent increase in cost. The addition of 1 or more lanes to a limited number of critical urban routes may become the required urban transportation strategy during the next 10, 15, or 20 years.

Since few urban freeways provide more than 4 contiguous through lanes and little traffic research has been done on those routes that do, the understanding of operations on such routes and of urban transportation systems under stress would be furthered by an investigation of the operational problems attendant on freeways having more than 4 lanes on each roadway. Those operational problems are likely to be related to at least 2 fundamental parameters: trip length distribution and interchange spacing. As an example of this relation, consider the case in which the mean urban freeway trip length is 6 miles (9.7 km) and interchange spacing is 1 mile (1.6 km). To achieve a reasonable balance of flow on each of 4 contiguous lanes, it is assumed that an entering vehicle will move to the farthest left lane and then return to the right lane to exit in a 6-mile (9.7-km) trip on the freeway. This condition produces 6 lane changes over the

length of the trip or 1 lane change per mile (1.6 km). Although this example simplifies the complex operations of a single vehicle trip, it does demonstrate the nature of the problem. Had there been an additional lane, the lane-change frequency would have increased such that 8 lane changes would have been required in the 6-mile (9.7-km) distance and resulted in a lane change every 0.75 mile (1.2 km). Since excessive lane changing may adversely affect highway capacity, the significance of the added lane on operational effects may be seen directly.

Proposed Research

1. Relate freeway traffic operational parameters such as speed, volume, density, lane-change frequency, and accident experience on specific saturated urban routes having 3 or 4 lanes to the trip length distribution and interchange spacing for that route.
2. Apply the relations found for the above routes to actual 5-lane roadways if any exist or to simulate the effect of a traffic-saturated 5-lane roadway to determine the nature of its operational problems.

21 Passing Sight Distance

Problem Statement

Until now, the roadway designer has had no satisfactory technique for determining the effect of the percentage of passing sight distances on speeds and level of service on 2-lane, 2-way rural highways. A North Carolina study investigated the relations between the independent variables of percentage of the total length of a section of highway marked with no-passing barriers and the traffic volume input and the dependent throughput variables of delay, attempted and completed passes, number of vehicles passed in multiple passes, emergency indicators, and speed change cycles. Such relations were developed by employing a calibrated and tested digital computer model. The model is applicable to 2-lane, 2-way rural sections of highway approximately 5 miles (8 km) long, with 2-way volumes between 100 and 1,200 vehicles per hour, any directional distribution of 2-way volumes, any percentage of medium trucks (single-unit), any percentage of heavy trucks, grades no greater than ±8 percent, and little or no side-road traffic volume. Regression equations and graphs developed for these variables from the model and other data from the study provide significant insight into the effect of the percentage of passing sight distances on speeds and level of service on 2-lane rural roads. Still, the results do not account for employment of various passing zone signs, markings, and laws.

The signing and marking of no-passing zones is a vital protective measure for motorists. Present criteria for no-passing zones in the United States are based on measurements of driver and vehicle performance conducted more than 25 years ago and on assumptions that may not be valid today in the widening variety of traffic and geometric situations to which they are being applied. Yet, there is considerable disparity among different users as to the nature and meaning of no-passing zones established on highway curves and in areas where passing must be prohibited because of inadequate sight distances or other special conditions. These deviations can usually mislead motorists and subject them unnecessarily to hazard or arrest or both.

The Manual on Uniform Traffic Control Devices indicates that, where passing must be prohibited, a no-passing zone shall be marked by either a 1-direction or 2-direction

pavement marking. Subject to this requirement, various permissive methods are given for defining a no-passing zone: (a) regulatory pavement markings with no signs, (b) DO NOT PASS sign with no regulatory markings, (c) DO NOT PASS sign with regulatory markings, (d) NO PASSING ZONE warning sign with regulatory markings, (e) DO NOT PASS and NO PASSING ZONE signs with regulatory markings, (f) DO NOT PASS and NO PASSING ZONE signs with no markings. Methods b and f would be applicable only on unpaved roads or on paved roads where lane lines are not marked.

Regulatory devices are insignificant and unenforceable without appropriate legislation to give them meaning and authority. Most jurisdictions in the United States consider the signs and markings regulatory in character and enforceable under the law, but a few of them treat them as advisory only and post messages such as UNSAFE TO PASS. They also sign or mark both vertical and horizontal curves although a few limit their use to vertical curves only.

The Uniform Vehicle Code, after which the laws of many states are closely patterned, provides for the use of either signs or markings to define a no-passing zone. This is not entirely consistent with the manual requirements, which indicate that painted markings shall be placed wherever centerlines are installed. Physical conditions and administrative problems vary by location. Those responsible for traffic operations where there are mountains or rolling terrain have a much greater burden than others for placement and maintenance of signs or markings for no-passing zones. Where snow conditions exist during great periods of the year, the markings alone have serious limitations and may not suffice. The waiver of sovereign immunity in road and traffic operations in certain locations now confronts such operators with liability claims for any failure to maintain signs and markings in clearly discernible conditions the year round whenever such negligence can be established as an approximate cause of an accident.

Proposed Research

1. Develop a factual basis for the review, validation, or modification of warrants and criteria for designating no-passing zones on 2-lane, 2-way highways and recommend modifications.
2. Develop comprehensive recommendations and guidelines for an improved, modern system of no-passing-zone control that can be applied uniformly and consistently through various countries for the safety and benefit of all drivers.
3. Determine the action that must be taken to implement or legalize any regulatory device controlling no-passing zones.

22 Effect of Median Type on Snow Removal

Problem Statement

Snow removal has been one of the major highway maintenance jobs during winter. Several different approaches have been suggested for removing snow. The electric heating cable system has been used to melt the snow that falls on sidewalks, on short stretches of pavement, or on steep ramps. In downtown areas, snow from heavy falls is loaded into trucks and hauled away. However, in most cases, the snow is simply bladed by various kinds of plows and thrown to the roadside. In the general operating procedure, snow on the inside lanes is plowed toward the median and on the outside lanes toward the right shoulder. This procedure works well on sections with depressed medians,

for the melt flows into the median ditch and away from the roadway. However, when the medians are raised or flush, the melt drains back onto the pavement and freezes when temperatures go below the freezing point. The resulting slick spots can be quite unexpected and, of course, hazardous. Even when temperatures are above freezing, the spray from such drainage can be annoying and also hazardous.

Proposed Research

1. Study how the snow-removing procedure and efficiency can be affected by the different types of medians, especially by the flush and raised medians.
2. Optimize the snow-removing efficiency and minimize the hazard by modifying the operating procedure.
3. Develop designs of flush and raised medians that will improve the snow-removing efficiency.
4. Consider the economic factor of this improvement.

23 Effect of Short Climbing Grades on Urban Freeway Operations

Problem Statement

Urban freeways carrying mixed traffic under near-capacity conditions appear to experience speed reductions where level sections become short climbing grades. In certain cases the reduction in speed below a critical level appears to produce unstable flow requiring a reduction in demand until the flow recovers to a stable condition. For certain sections of urban freeways, these conditions may be observed during rush periods. As a corollary to the critical operating condition of a climbing section, flow beyond the crest of a climb has been observed to return to a stable condition. Although much research has been performed on vehicle climbing characteristics and the relation of road profile to capacity, this work has largely been oriented to rural conditions and has tended to concentrate on large differences in elevation and on relatively long climbing distances.

Proposed Research

Collect data on vehicle mix, speed changes, capacity, grade, and vehicle operating characteristics of urban roadways that have climbing grades.

24 Joint Usage of Roadway Shoulder by Motor Vehicles and Bicycles

Problem Statement

The shoulder provides for accommodation of stopped vehicles for emergency use and for lateral support of base and surface courses. As bicycling continues to increase, ways must be found to integrate this mode into the total transportation system. Much study and effort are being directed toward the development of separate bikeways, a reasonable but costly approach. A less costly supplementary approach to providing safe bicycle paths might be to use a portion of existing roadway shoulders for bicycles.

Proposed Research

1. Determine the effects of joint shoulder usage with respect to the safety of bicyclists and motorists; the capacity of the roadway, intersections, and driveways; and the conflicts of vehicles, bicycles, and pedestrians.
2. Determine minimum shoulder surface standards, lateral clearances, and control devices (signs, markings) required for safe bicycle use.
3. Determine what type of modification or improvement would be required for existing substandard shoulder types to meet the above standards for joint usage.
4. Perform a cost-effectiveness analysis of making the indicated improvements.
5. Develop warrants for joint shoulder usage if the analysis indicates feasibility based on reasonable bicycle volumes.

25 Current Vehicle Operating Characteristics Related to Design Parameters

Problem Statement

The design of highways today is based partially on vehicle operating characteristics developed in the mid and late 1950s. Therefore, the question is raised as to whether the vehicles today have the same operating characteristics as those used to develop many design parameters related to acceleration, deceleration, and stopping.

Proposed Research

1. Analyze the vehicle operating characteristics of today's vehicles related to the actions of secondary stopping and recovery off the roadway.
2. Determine the degree of difference, if any, between the vehicle characteristics in 1950 and today.
3. Study and evaluate the effect that any differences found between the 2 populations of vehicle operating characteristics have on design parameters relating to secondary stopping and recovery off the roadway.
4. Determine what changes are needed in the design parameters and suggest new design parameters.

26 Safety of Highway Shoulders

Problem Statement

To justify highway shoulders, many studies have attempted to show their safety effectiveness but without success, for they have looked at total accident statistics. In the process, they may have washed out the effect of paved shoulder width on certain kinds of accidents, particularly skidding accidents and off-the-road accidents. In both kinds of accidents, the paved shoulder provides additional primary recovery area that is substantial for flat-angle encroachments.

Proposed Research

Collect and analyze accident data on selected roads with and without paved or stable

shoulders in a way devised to isolate the effect of shoulders on accident occurrence.

27 Noise Measurements

Problem Statement

If noise could be described on the same basis for all modes of transportation, then a decision on which mode would have the least impact could be made.

Proposed Research

Develop a methodology for calculating and evaluating on a comparative basis the noise impact of various modes of transportation.

28 Air Quality Measurements

Problem Statement

Currently, air quality measurements require considerable time. The increasing number of environmental impact statements is creating a problem in terms of the personnel, time, and equipment required to take measurements. A methodology is needed that would significantly reduce the amount of time necessary for making field measurements.

Proposed Research

Develop a procedure for making air quality measurements consistent with the personnel and time restrictions of governmental agencies.

29 Effects of Fog on Traffic Operations

Problem Statement

In the past few years, a number of multiple car and truck accidents have occurred in areas of heavy fog in southern California, upper New Jersey, and Connecticut. This type of accident normally occurs in areas of intermittent fog, where vehicles go in and out of dense fog and relatively clear areas. In Connecticut, highways pass through several depressions in the terrain where fog has a tendency to accumulate.

Proposed Research

1. Investigate whether a commercial instrument exists that measures humidity and temperature and can be effectively used as a fog monitor and, if none exists, investigate the feasibility of a solid-state system that can measure relative humidity, temperature, and backscatter of light and then correlate these measurements to actuate roadway signs on a continuous basis.

2. Determine driver behavior when he or she enters a dense patch of fog (use a driver simulator to obtain driver reaction data on variations in speed, headways, and tracking, in urban and rural areas, and under varying traffic volume conditions).
3. Suggest programs or methods to use findings in accident prevention under conditions of reduced visibility.

30 Factors Involved in Single Accidents

Problem Statement

Several states with mountainous terrain and many miles of narrow 2-lane highways on curvilinear alignment have a disproportionate share of single-car accidents. Generally, an automobile accident has several contributing factors or causes. However, in this case, it may be that the geometrics of the highway (as a group of factors) is the most significant factor. Other factors such as condition of the pavement (wet, icy) and condition of the driver (intoxicated, sleepy) must be considered.

Proposed Research

1. Determine the relation of highway geometrics to single-car accidents.
2. Determine the factors, particularly roadway geometrics, involved in single-car accidents and their relative importance.
3. Suggest programs of corrective measures for preventing single-car accidents.

Freeway Operations*

The Committee on Freeway Operations invested a considerable effort in a priority ranking analysis of its problem statements. Statements 1 through 8 were given the highest priority; each was clearly separated and distinct from the others as to priority. The remaining 27 statements can be considered to be of about equal priority.

1 Handling Vehicles Disabled or Involved in Accidents

Problem Statement

The operation of urban freeways is continually disrupted by disabled vehicles or those involved in accidents. Freeway capacity at the incident is decreased significantly below normal capacity of the remaining open lanes. In addition, the longer the vehicles remain on or near the roadway, the more the resulting congestion is compounded. Research is needed to determine the frequency of incidents of varying degrees of severity, the degree of assistance needed, the methods of removing the vehicles so that they do not constitute a hazard to traffic or a visual distraction capable of slowing traffic and causing congestion, the most effective types of equipment necessary to accomplish this task, and the procedures for storing or disposing of the vehicles until they are retrieved by their owners.

Proposed Research

1. Determine the frequency of occurrence of incidents of various types and severity.
2. Determine the degree of assistance needed to remove each of these types of incidents from the roadway.
3. Conduct a study of various techniques and equipment being used to handle disabled vehicles and evaluate the effectiveness of each.
4. Determine whether other means not now being used might be more effective.
5. Determine the quantities of the various types of equipment necessary to accomplish this removal.
6. Determine the quantities of the various types of equipment required to handle the anticipated number of incidents of each degree of severity.
7. Determine methods and places to securely store these vehicles until retrieved by their owners.

2 Methods for Detecting and Identifying the Character of Freeway Incidents

Problem Statement

A major portion of the congestion on urban freeways is caused by incidents occurring in or near the roadway. The incidents block lanes or reduce traffic speeds to such a degree that even reasonable traffic demands cannot be satisfied. The most effective means of incident disposal cannot be implemented until the incident is detected and evaluated with regard to the appropriate assistance required. The magnitude of the effect of the incident is compounded as the response time to the incident increases. The ideal system for incident detection is one in which the entire area of the roadway is observed and information is provided on the nature of the incident so that the appropriate assistance can be dispatched in the quickest possible time. Research is

necessary to develop a detector capable of providing this type of information, the equipment configuration necessary to provide adequate coverage of the roadway to provide meaningful information, and the necessary programs and evaluation techniques necessary to reliably identify incidents, reject false incidents, and identify the character of the incident so that appropriate assistance can be dispatched.

Proposed Research

1. Classify the various types of incidents and identify in detail their traffic flow characteristics.
2. Identify the desired function of the detector and the detection system.
3. Prepare a functional specification and develop a detector capable of reliably carrying out the desired function.
4. Prepare a functional specification and develop the equipment configuration necessary for a candidate system or systems capable of performing the desired function.
5. Develop the necessary techniques and programs that will enable the detection system to quickly and reliably respond to, qualitatively evaluate, and warn of incidents on the freeway (a high degree of confidence must be sustained by reliably sensing true incidents and not generating alarms by the apparent detection of false incidents).

3 Standardized Measurement Criteria and Techniques for Evaluating Vehicle Detectors for Traffic Flow Measurements

Problem Statement

A variety of vehicle detection devices, which are required to implement automated measurement of traffic flow characteristics, are now on the market. They detect passing vehicles in a variety of ways: change in inductance of a loop buried in the roadway, disturbance in earth's magnetic field, actuation of treadle by weight of vehicle, actuation of pneumatic tube by weight of vehicle, interruption of light beam, and radar return (both radio frequency and ultrasonic). The successful application of this detection equipment is influenced by many variables, including vehicle size, temperature range, and installation geometry. Technical data from the manufacturers are generally inadequate to make quantitative performance comparisons. Research is, therefore, needed to classify vehicles and quantitatively define the vehicle characteristics that influence the detector, to classify and define typical application geometries, to define test equipment and test methods for measuring the phenomenon being used for vehicle detection, and to establish the merits of each detector classification.

Proposed Research

1. Obtain a variety of vehicle detector types for testing.
2. Make measurements of detector performance for each of the various combinations of variables.
3. Classify the resultant data and define standards for future measurements and comparison tests, i.e., for inductive loop detectors, loop configurations, and vehicles of different sizes and ranges of magnetic permeability.
4. Define figures of merit for detectors, i.e., for an inductive loop detector, the figure of merit could be the change of inductance obtained from a standard vehicle in a certain position on a standard loop geometry.

5. Determine minimum detection thresholds so that the probability of detecting a vehicle is maximized and false detections are minimized.
6. Compile the results in a report by detector category so that a user can select a detector suitable for the measurements to be made and will have quantitative numerical values of detector performance required for that purpose and the description of the measurement techniques required to verify whether the detector performance is being realized.

4 Scheduling Freeway Maintenance Activities

Problem Statement

Maintenance activities on freeways can result in time-consuming congestion and delay to motorists and in increased accident potential, whether the work is within or outside the travel way. At the same time, the cost of maintenance work on freeways is high because of the need to provide elaborate traffic control through the work area, the necessity of limiting certain types of work to light traffic periods, and the low productivity resulting from limited working area adjacent to the heavy volume or high-speed traffic flow. Under certain conditions, fully closing one or both freeway roadways during major structural repair may be economical. The cost to the maintaining agency may be lessened if complete closure results in a much faster return to normal operation. Improved techniques for scheduling maintenance activities are needed to minimize the time required for operations that adversely influence traffic movement and to optimally balance maintenance costs and adverse traffic effects. Improved methods of controlling traffic through work areas are needed to minimize traffic delay, disruption, and accident potential and to reduce maintenance work costs. Guidance is needed on the conditions under which closure of a freeway roadway may be justified for extensive maintenance work.

Proposed Research

1. Review and summarize present practices on freeway maintenance operations, giving particular attention to methods of scheduling maintenance activities to minimize traffic disruption, and collect and analyze data on freeway maintenance costs and the traffic effects of freeway maintenance activities.
2. Develop standard practices on the selection of materials and equipment that will minimize the time for the frequently encountered maintenance operations.
3. Prepare a manual on freeway maintenance operations, including techniques for scheduling maintenance activities; practices for the control of traffic through work areas, and guidelines for determining the feasibility of constructing temporary detours or otherwise allowing full closure of a freeway roadway; practices for the commonly encountered freeway maintenance activities such as traffic striping, sweeping, landscaping maintenance, guardrail repair and painting, and roadbed and surfacing repairs; and practices on the selection of materials and equipment to minimize the time for maintenance activities that adversely affect freeway traffic operation.

5 Traffic Control Through Freeway Construction Areas

Problem Statement

The control of traffic through work areas on freeways requires treatments markedly different from practices that are acceptable on surface highways. The high travel speeds and heavy traffic volumes generally found on freeways impose special problems in providing adequate warning and direction of traffic affected by maintenance and construction operations. The adverse effects of work activities within or adjacent to the roadway are more far-reaching and more costly to the freeway user than the effects of similar activities on normal highways. There is considerable variation in the operational treatment of construction and maintenance areas. Standard practices on the control of traffic through work areas should be developed for the guidance of designers, contractors, and maintenance personnel.

Proposed Research

1. Review and summarize present practices on the control of traffic through work areas on freeways.
2. Evaluate alternative means of controlling traffic through work areas and develop and test innovative methods and devices.
3. Develop recommended standard practices for traffic control through work areas, including design, placement, and use of traffic control devices.

6 Service Facilities on Freeways

Problem Statement

As the urban and rural freeway system nears completion and the use of these facilities increases, more services must be provided. Research is needed on the requirements of travelers so that recommendations can be made for providing improved service facilities.

Proposed Research

1. Conduct a literature search for studies pertinent to this research problem.
2. Determine the service needs and desires of freeway travelers.
3. Recommend implementation plans for providing the required services.
4. Evaluate existing services and recommend improvements.

7 Freeway Accidents and Environmental Elements

Problem Statement

Freeway environmental elements often contribute to and are sometimes the cause of freeway accidents. Among these environmental elements are weather conditions, time of day, landscaping, and freeway design. Research is needed to identify, quantify, and

relate freeway accidents and various environmental elements. The research should result in recommendations leading to early development of corrective measures to reduce the effect of environmental elements on freeway accidents.

Proposed Research

1. Review earlier studies.
2. Review accident data to uncover effect of freeway environmental elements on freeway accidents.
3. Determine cause and effect relation between freeway accidents and environmental elements.
4. Recommend immediate and future remedial measures.

8 Impact Attenuators and Vehicle Redirection Devices

Problem Statement

Several types and designs of impact attenuators and redirecting systems are available, and experience and trial installation have indicated that some can be considered operational. The lowest priced unit consistent with satisfactory performance should be specified or developed. Research is needed to determine acceptable levels of performance regarding vehicle and driver damage and safety to other drivers for various roadway, volume, and dynamic conditions and to develop, investigate, and improve transitions from impact attenuators to redirection devices.

Proposed Research

1. Review past and present studies and performance records and designs of impact attenuating and redirecting devices.
2. Consider some or all of the following influencing factors in selecting warrants for impact attenuator use: alignment present (vertical and horizontal), delineation, illumination, cross section, shape, size, and color of hazard, background color, number and types of choices at bifurcations, escape areas, frequency of past contacts by vehicles, volumes and types of traffic, time of peaks, other possible treatments, and possible elimination of problem.
3. Prepare and test samples for a matrix chart recommending applications for existing specific devices.
4. Consider the basic dynamic influencing factors and needs for transition systems.
5. Design and test improved transition systems such as twisted sloping end sections, vertical shearing or other special post connections on sloping end sections, triggered hooks, nets, or special devices on end sections, triggered horizontal redirecting devices to use vehicle kinetic energy to redirect vehicle, and post extended above rail.

9 Education Curriculum and Licensing Standards for Freeway Driving

Problem Statement

Driver education curricula and driver licensing standards generally are not oriented to

freeway driving. Research is needed to determine what the unique characteristics of freeway driving are and how this information can be made a part of the normal driver education curriculum and licensing standards.

Proposed Research

1. Review existing material, including material published by the TRB Committee on Freeway Driving and by the various states and the Federal Highway Administration in curricula and standards.
2. Identify those characteristics of freeway driving that are unique to freeways and that would not normally appear in existing material, e.g., signing including interstate numbering system, positioning of through lane versus exit lane arrows, ramp versus freeway reflector colors, gore markings, and service symbols; driving maneuvers including acceleration lanes and merging, deceleration lanes, lane changing, braking, weaving sections, and break-down lanes; and special safety procedures including tailgating and chain reaction collisions, aborted merging maneuvers, and safety when repairs are made in a break-down lane.
3. Rank the material in order of importance.
4. Rank the material in order of acceptability in terms of conforming to existing state ordinances.
5. Correlate the material with the most current highway standards.
6. Recommend a staged implementation plan, including specific recommendations, to state ordinances.

10 Regulation of Vehicle Design Elements Related to Roadway Design

Problem Statement

The system involved in moving goods and services from place to place by free-wheeled vehicles necessarily includes roadway, vehicle, and operator. A good deal of attention has been given to each area separately, yet it seems axiomatic that they all must be considered as concurrent elements of a single system. Historically, variations in vehicle design have made roadway facilities obsolete long before their time. Research is needed to identify the controllable elements of vehicle design and roadway design that have direct bearing on one another and to formulate procedures by which interdependent changes can be brought about on a related basis. The study should consider the need for and means of regulating changes in vehicle design so as to prevent uneconomical obsolescence of existing highways.

Proposed Research

1. Review past and current research pertaining to the interrelated elements of vehicle performance and roadway design and review present means of controlling the related design features.
2. Prepare a state-of-the-art summary of the results of the research review and identify the controllable elements of vehicle-roadway design in order of importance.
3. Formulate means of regulating the related design elements to achieve an optimal level of performance of highway facilities, considering the investment of both public and private funds.

11 Spot Improvement Construction Program Priorities

Problem Statement

Spot improvement construction is a necessary component of freeway maintenance. The higher speeds attainable on freeways and the increased demand for those facilities require continual improvements. Historically, cost-effectiveness methods for project priorities have contained uncertainties and inaccuracies. Research is needed to make cost-effectiveness analysis reflect more fully the total cost and value of an improvement. This research should result in improved cost-effectiveness methods applicable to preparing spot improvement construction program priorities.

Proposed Research

1. Review past and present methods.
2. Determine factors to be included in the development of possible alternatives.
3. Evaluate possible alternatives leading to recommended methods.

12 Pavement Marking Systems for Northern Climates

Problem Statement

A working scheme is needed that will provide adequate driver guidance under wet and night conditions and during all seasons and that will have adequate durability and retention for year-round guidance. This evolves in northern climates from 2 factors unique to those latitudes: cold weather and snowplowing. Cold weather precludes application of conventional markings to roadways, and snowplowing removes all earlier applications placed in warm weather. A third factor, of course, is wetness that removes visibility year-round, particularly at night.

Proposed Research

Study ways to eliminate or minimize the effects of these factors.

13 Traffic-Responsive, Changeable-Message Speed Signs

Problem Statement

Variable speed signs for control are used on freeways in Detroit, Seattle, and New Jersey. The results indicate that motorists ignore messages unless there is an obvious reason for obeying them. Coupling speed information with an informative message like ACCIDENT AHEAD works better, but the time between when the message is presented to the driver and when the driver is able to confirm its truth is critical. This time needs to be determined.

Proposed Research

1. Determine a set of events that should have a corresponding speed associated with it.
2. Determine whether reinforcing messages are required for each event and what the message should be.
3. Determine acceptable ranges of confirmation times for each unit.
4. Determine whether measurable traffic characteristics can be used to determine that an event has taken place.
5. Develop representative geometries of the relative location of detection equipment, speed sign, and reinforcing message sign and the location of the event for each of the selected events.
6. Recommend a set of experiments for each of the events that have met all of the above criteria (these experiments would be conducted in a subsequent research effort to evaluate motorist response to the traffic-responsive speed signs).

14 Ice and Frost Warning Devices for Freeway Bridges

Problem Statement

The research, development, and evaluation of systems to detect frost and ice are well under way and should not be the prime consideration for this study. What is needed is an economic justification by cost analysis of methods to provide freeway bridges free of unsuspected ice and frost. The alternatives to be studied are (a) continue deicing bridges as needed, (b) use simplified detection equipment and deice automatically even if not needed, (c) use better detection equipment and alert and/or spread deicing materials as frost and ice form, and (d) build predictive model and use equipment capable of predicting before ice and frost form. It may become necessary in the near future to consider the ecological implications of using certain deicing materials. Other types of chemicals or means of removing the frost and ice and alerting the driver may then become the important factors.

Proposed Research

Provide a cost-analysis method to determine the best method to detect ice and frost, to remove the slippery condition, and to alert drivers.

15 Optimum Design Level for Traffic Characteristics and Traffic Control Devices

Problem Statement

The level of design achieved for traffic characteristics and traffic control will naturally determine the quality of the service to be provided. Among the factors to consider are the costs associated with an incremental improvement in the level of design and the consequences of high failure rates. Research is needed to determine the sensitivity of effective traffic operation to various levels of design for traffic characteristics and traffic control devices. This research should result in the determination of an optimum design with acceptable failure rates.

Proposed Research

1. Review past and current research pertaining to optimum level of design for traffic characteristics and traffic control devices.
2. Determine factors to be considered and their relative importance.
3. Recommend optimum level of design for traffic characteristics and traffic control devices.

16 Guidance Information Requirements of Freeway Drivers

Problem Statement

Freeway guide sign requirements are thought to differ appreciably for 4 categories of freeway drivers: local resident who is familiar with the roadway, local resident who is not familiar with the roadway, nonresident who is familiar with the roadway, and nonresident who is not familiar with the roadway. In the design of freeway guide signs, the emphasis given to each category varies from jurisdiction to jurisdiction and sometimes from project to project within a given jurisdiction. Variations in sign design relate to freeway names, use of place names versus compass direction, and use of exit numbers versus connecting street or community names. Research is needed on the relative importance of guidance information for each category of drivers on both urban and rural freeways and on the type of information needed for each category. Further study is needed to determine the best type of signing for all freeway drivers, that is, whether the signing should be designed specifically for one category or for all categories, possibly at varying levels. Concurrently, research is needed on the design of guide sign features that will best provide the needed information.

Proposed Research

1. Determine the principal information needs of each of the 4 categories of freeway drivers.
2. Determine the relative importance of providing guide sign information to each category of drivers on both rural and urban freeways.
3. Identify guide sign features that will satisfy the most important and the less important information needs.
4. Evaluate present practices in the design of freeway guide signs and make recommendations on design changes to better serve drivers.

17 Freeway Guide Signs

Problem Statement

Factual data are lacking on the information freeway drivers need from guide signs. Research is needed on the design of messages to adequately inform the driver and on the optimum size and placement of freeway guide signs and their components. Practices in the design and placement of guide signs for freeways have evolved from those for other highways and have resulted in instances of unnecessary and confusing signing.

There is no uniformity in the design of sign legends, in the style and size of letters, in the use of symbols, and in the placement of sign structures. Freeway signing practices should be reviewed and evaluated based on driver information needs.

Proposed Research

1. Review the results of previous research on freeway driver information needs.
2. Formulate and conduct additional research studies to identify freeway driver information needs related to guide signing.
3. Review present practices in the design of freeway guide signs and evaluate those practices by using criteria for driver information needs.
4. Prepare recommendations for the design and placement of guide signs to provide an optimal level of information to the driver, considering factors such as legend design, letter size, letter and background color, use of standardized formats and symbols, and placement of signs with respect to the roadway and points of egress from the freeway.

18 Prevention of Wrong-Way Driving on Freeways

Problem Statement

Current work in the area of wrong-way driving has concentrated on the use of fixed-message signing and the geometry of the exit ramp such as the use of curbing to make it difficult for a car to enter an exit ramp. These techniques, however, are not enough, for people can still get on ramps the wrong way. Research needs to be done on what to do about the driver who gets on the exit ramp the wrong way in spite of the precautions. Detecting a wrong-way driver may be accomplished with commercially available directional detectors. The key question then is, What can be done after the driver is on the ramp going the wrong way?

Proposed Research

1. Review the work that has been done to date.
2. Select for study several of the most commonly used geometries of exit ramps.
3. Assume that the driver is on the ramp and, for each of the selected geometries, establish where detectors should be placed, investigate changes in the geometry for escape lanes and turning the motorist around in a safe manner, and investigate actuated illuminated warning signs and mechanical devices and barriers that can safely perform the desired function.
4. Submit recommendations for experiments to be conducted in the field.

19 Screening New Traffic Control Devices

Problem Statement

Most cities experience traffic control problems, particularly as traffic volumes have become heavier, and need new traffic control methods and devices. The most appropriate method or device should have the characteristics of reliability, flexibility, and

ease of maintenance. Research is needed to devise standardized laboratory methods for screening alternate proposed new traffic control devices and methodologies.

Proposed Research

1. Determine the importance of traffic control device characteristics and their relative position on a scale (i.e., mean time between failure, ease of maintenance, cost).
2. Evaluate alternate proposed new traffic control devices based on the characteristics.

20 Roadway Tactile Stimuli

Problem Statement

The safe operation of vehicles sometimes requires that the driver's attention be attracted to an unusual or unpredictable situation such as a freeway ending, lane drop, construction area, temporary maintenance, and freeway changes. The standard traffic control devices such as barricades, lane markings, warning lights, signals, signing, and channeling are usually adequate at most places. But at problem areas, additional stimuli have been provided by road surface devices such as raised markers, rumble strips, and pavement configurations.

Proposed Research

1. Study safety of driver when vehicle strikes tactile stimulus.
2. Study placement, size, and installation procedures.
3. Develop warrants for volumes, speeds, noise, and roughness related to roadway condition.

21 Single-Vehicle Run-Off-Roadway Accidents

Problem Statement

To better locate, estimate, and evaluate the effect of impact attenuators and redirection systems require that more definite quantitative information be available on the frequency, location, and characteristics of single-vehicle ran-off-roadway accidents, particularly the vehicle path, velocities, and recoverability of the driver.

Proposed Research

1. Review past and present studies and data and prepare state-of-the-art summary.
2. Plan and carry out a statistically sound study to provide additional quantitative data on the following characteristics of the ran-off-roadway accidents: measurements needed, measuring methods available, location, time of day, velocity initially and along path, direction wheels turned, condition of driver, point of driver alert, vehicle type, vehicle path and final position, heading and condition of vehicle, geometrics and operational devices including informational signs in the area, and perception distraction factors.

22 Traffic Operation and Safety Problem Locations

Problem Statement

Detection of safety problem locations is one of the most important programs to reduce traffic accidents. Factors that lead to unsafe conditions include congestion, physical condition of the road, and lack of law enforcement. Research is needed to develop standard methods for detecting and priority listing traffic operation and safety problem locations. Research should also be conducted to develop standard methods for the evaluation of corrective measures.

Proposed Research

1. Determine factors contributing to unsafe conditions.
2. Examine existing design and traffic control criteria resulting in these unsafe conditions and recommend necessary changes.
3. Develop standard methods for detecting safety problem locations.

23 Driver Aid for Judging Distance and Speed on Freeways

Problem Statement

Studies show that drivers driving at high speed on freeways have considerable difficulty judging distance, absolute speed, and closing speeds. These difficulties present problems in determining when to decelerate for toll booths and ramps and how much distance is required to perform a safe braking maneuver. Equipment similar to that used by airplane pilots for this purpose appears to be prohibitively expensive. Research is needed on how to feasibly provide visual or audible cues to aid the driver. The spacing of paint stripes approaching toll booths has been used to assist the driver in braking maneuvers. This could be used elsewhere. Rumble strips might also be used in a similar manner to combine both visual and auditory stimuli. Exit signing could be similar to that on the German autobahns. Those signs are equally spaced from an exit; the farthest out sign has 3 diagonal lines on it, the second has 2, and the third has 1. The sign also has the numerical distance. The drivers, by custom, get used to the spacing and normally look for the diagonal stripes. There are 2 aspects of standardization of the location of an informative sign ahead of a decision point: (a) Use the same spacing all the time so people get used to it and (b) locate the sign in terms of the time it takes to make a decision at the maximum or high average speeds experienced on the road, i.e., locate the sign far enough upstream so the motorist can make a decision before he or she must execute a maneuver.

Proposed Research

1. Examine driver aid techniques that are relatively easy to implement such as paint, signs, and standards of signing.
2. Document guidelines, numerical tables, and suggestions for improving existing standards.

24 Brightness Levels and Warrants for Freeway Signs

Problem Statement

Present practice in the design of freeway guide signs, route markers, and information signs includes the use of distinctive sign background colors. Information clues provided by the background color should be available to the driver at night as well as in daylight. Two means are available for providing nighttime visibility of sign colors: reflective sheeting and direct illumination. Directly illuminated signs most commonly use exterior-mounted lighting fixtures. Additional information is needed on the relative merits of reflective and illuminated signs under various conditions. Specifically, information is needed on the conditions under which the more costly installation of directly illuminated signs is justified. Limited research has been done on the proper brightness levels of sign legend and background for either directly illuminated or reflective signs. Information is needed on these aspects of sign design for varied conditions.

Proposed Research

1. Review current and past research on the relation between sign brightness and legibility.
2. Prepare a state-of-the-art summary.
3. Identify needed additional research to ascertain optimum brightness levels of sign legend and background for several types of freeway signs and for a variety of conditions.
4. Prepare recommendations on proper brightness levels for directly illuminated signs and for signs having reflective sheeting backgrounds.
5. Formulate recommendations on the desirable qualities for reflective sheeting for a representative variety of sign types, sizes, colors, and placements.
6. Identify the conditions under which directly illuminated signs should be used and the conditions under which reflective materials are appropriate for freeway signs.

25 Snow Removal and Ice Control Methods

Problem Statement

Although many varied attempts have been made to achieve a low-cost, satisfactory method for keeping pavement surfaces clear in winter, most methods fall short of desired results because of either destruction of paint lines or high initial or continuing costs. Research is needed to provide a snow and ice control system that will not destroy features such as paint lines and delineators and yet will be reasonable in cost.

Proposed Research

1. Review past and current research pertaining to the problem of nondamaging snow and ice control.
2. Prepare a state-of-the-art summary.
3. Prepare a study plan to supply information not already available toward developing a satisfactory solution for limited or total application.

26 Slow-Moving Vehicles on Freeways

Problem Statement

Certain types of vehicles, including special purpose maintenance equipment, such as traffic stripers and sweepers, and vehicles carrying unusual loads, such as overweight vehicles traveling under permit, must necessarily travel on freeways at speeds considerably below prevailing traffic speeds. These vehicles present potential for traffic accidents either involving the slow-speed vehicles or resulting from abrupt speed changes or passing maneuvers by following vehicles traveling at much higher speeds. Some jurisdictions protect slow-moving equipment and guide and warn other traffic by practices such as the use of a large truck that follows a traffic striper or sweeper and is equipped with unusually large signs or warning devices that are visible for a considerable distance. However, there is no uniformity of treatment among jurisdictions.

Proposed Research

1. Review and summarize present practices on the treatment of slow-moving vehicles on freeways.
2. Analyze the adequacy of existing practices.
3. Develop recommended standard practices to provide adequate protection for the slow-moving vehicles and to minimize the hazards to other traffic.
4. Evaluate the need for improved devices for warning and directing traffic approaching slow-moving vehicles.
5. Develop performance requirements and prepare specifications for prototype development and test.
6. Analyze the performance characteristics of slow-moving equipment frequently used on freeways.
7. Evaluate the feasibility of redesigning existing equipment or of developing new equipment design to provide more suitable operating characteristics for freeway use.
8. Prepare performance specifications and specifications for prototype development.

27 Information Processing Characteristics of Freeway Drivers

Problem Statement

The reaction of freeway drivers to external stimuli is of importance in freeway design and traffic control and depends on the drivers' information processing characteristics. Research is needed to identify the information processing characteristics of freeway drivers. This research must be directed to the development of an understanding of the basic limitations, capabilities, and reactions of the freeway driver with regard to information processing and of the distribution of these characteristics among the driver population.

Proposed Research

1. Conduct a literature search pertaining to basic human information processing characteristics.
2. Determine those factors important to freeway driving and indicate their pertinence to freeway design and traffic control.

28 Alternate Routing in Highway Networks

Problem Statement

Whenever there are capacity-reducing incidents or conditions on freeways, information should be supplied to drivers on alternate routes available in the same corridor. Research is needed toward developing procedures, techniques, and equipment for optimizing both advisory and mandatory alternate routing in highway networks.

Proposed Research

1. Review past and present studies and performance records and designs of special traffic information and instruction signs.
2. Gather and organize information on types, locations, and frequency of problems and information needed by drivers on alternate routes.
3. Identify and quantify levels of need for supplemental systems and signing.
4. Identify one or more types of supplemental systems based on capacity and environmental level of the alternate routes.
5. Develop optimum shape, size, and message for proposed supplemental signing.
6. Recommend automatic or other methods for actuating supplemental instructions and signing.

29 Design and Signing of Lane Drops

Problem Statement

Freeway designs frequently include changes in the number of lanes on the through roadway. When a lane ends, generally at an exit ramp or interchange transition roadway, a hazardous condition can result. General design treatments have been recommended to minimize the adverse operating features of necessary lane drops. However, research is needed to evaluate the effectiveness of the recommended treatments and to develop more specific design recommendations covering a greater number of conditions found in practice. Similarly, current practices on signing and delineating lane drops should be reviewed and summarized, and recommended practices should be developed for use in the design of new facilities and reconstruction of existing freeways. The research should take into account the need for advance warning of the change in roadway conditions and the need for delineating the transition area.

Proposed Research

1. Review past and current research and present practices on the design of lane drops on freeways.
2. Review past and current research and present design practices on signing and delineating lane drops, including advance warning of the change in condition.
3. Prepare a state-of-the-art summary of the review.
4. Evaluate present design practices and formulate recommendations for improved treatments for both future facilities and existing locations.

30 Processes and Factors That Determine Roadway Traffic Capacity

Problem Statement

The concept of capacity is fundamental to design of new installations and to the efficient use of existing facilities. Many assumptions and faulty criteria form the foundation of the present concept of capacity. Research is needed to define the processes and factors that determine roadway traffic capacity.

Proposed Research

1. Review past and current research pertaining to the problem of roadway traffic.
2. Prepare a state-of-the-art summary of the review.
3. Define the processes and factors that determine roadway traffic capacity.
4. Evaluate existing criteria and recommend necessary changes.
5. Develop recommendations for continuing research.

31 Warrants for Ramp Metering or Closure

Problem Statement

If traffic volumes continue to overload present freeways, ramp metering or closure may be more frequently used. Studies are needed develop warrants for or effects of metering and closure on capacity, accidents, inconvenience, and other modes of transportation.

Proposed Research

1. Identify and quantify effects of ramp metering and closure.
2. Discuss and recommend warrants or show curves or tables for selection of warrants for ramp metering and closure.

32 Capacity and Level of Service of Freeway Elements

Problem Statement

The freeway is made up of several components of various capabilities and quality depending on the level of service desired. A study should be made of the elements of the freeway design and operation and their influence on capacity for various levels of service.

Proposed Research

1. Review available information on quantitative effect of various designs of freeway components.
2. Develop a plan for obtaining any needed additional information.
3. Produce tables or graphs showing the influence of component design on capacity or quality of service of the facility.

4. Recommend points on these curves to produce optimum level of service.

33 Staggered Work Hours at Workplaces Along Airport Access Facilities

Problem Statement

Available land adjacent to the airport is an attractive location for industrial and commercial developments. Most of these developments are large employment centers that at times generate traffic volumes equal to or greater than that of the airport itself. In some urban areas these developments occur without the benefit of additional highway facilities. Consequently, both airport traffic and that generated by the many industrial parks, offices, hotels, and restaurants must be carried by the airport access facility. Since the peak-demand characteristics normally coincide, severe congestion results. Staggered work hours of the organizations along the access facility may reduce the effects of the concentration of trips in time.

Proposed Research

1. Make field studies to obtain complete quantitative data of travel patterns contributing to traffic congestion on airport access facilities.
2. Determine levels of traffic operation necessary to achieve desired levels of service.
3. Consult with selected organizations located along the access facility regarding objectives and feasibility of staggered work hours.
4. Conduct attitude surveys of employees to determine preferences for starting and quitting times.
5. Implement staggered work hour strategies.
6. Perform field studies to evaluate full effects of implementation, including the effects of volume changes throughout the affected travel area and effects of changed hours on the business and private lives of the employers and employees.
7. Document results and make recommendations for further implementation.

34 Airport-Related Directional Information Requirements

Problem Statement

The steady growth of air traffic and inadequate transit facilities to airports are placing an increasing number of airport trips on metropolitan freeway systems. Airport trips are made by those who have little knowledge of the proper route or the freeway system. Peak hours of airport traffic coincide generally with rush hours on the freeway system, and thus pressures are added to the demands of the route-finding task. Airport users are also usually under some form of time pressure to reach their destination. Research is needed that will define, quantitatively as well as qualitatively, the problem of proper directional guidance from and to airports and develop feasibile and practical solutions.

Proposed Research

1. Review the state of the art and current practices for giving airport-related directional guidance information.
2. Determine type of locations on the freeway system as well as at ramp terminals at which airport-related guidance information is needed.
3. Determine types of destination (e.g., downtown, civic center) for which guidance information is required for trips originating at the airport.
4. Develop potential solutions to the problem.
5. Test most promising solutions in the laboratory, in simulated trip conditions, or at actual test signing installations.
6. Recommend a solution that is sufficiently detailed as to form and location so that it can be submitted to the Federal Highway Administrator for inclusion in the pertinent manuals.
7. Investigate and define the problem of alternate routes, depending on the final destination within the airport or on traffic or other conditions, and develop a research program to find a solution that is applicable to metropolitan areas that have multiple airports as well as those that have only a single airport.

35 Interface Between Freeways and Airport Service Roads

Problem Statement

Although many airports have service roads within the airport, the connections between these service roads and the nearest freeway intersection are often inadequate. Traffic congestion at many airports frequently is affected by congested on- and off-ramps and excessive weaving movements between these ramps and the signalized intersection. These problems are indicative of the inadequacy of connections between the freeway and the airport service roads. Design guidelines are needed for the interface between the freeway and airport service road.

Proposed Research

1. Review and summarize present design practices for freeway and airport service road connections.
2. Evaluate alternative methods, including the application of direct connecting ramps, of accommodating traffic from the freeway to the airport service roads and subsequently back to the freeway.
3. Develop recommended guidelines for the design of the interface between the freeway and airport service roads to achieve an optimal level of performance.

Winter Maintenance

1 Controlled Testing of Deicing Chemicals on a Trafficked Test Installation

Problem Statement

In past years a number of tests of the effectiveness of chemical and abrasive treatment of ice-covered pavements have been made in the United States by state highway departments, university laboratories, and trade associations. These tests have resulted in many empirical rules of thumb, but inadequately controlled test conditions have resulted in a potential for significant overuse of chemicals. Laboratory tests generally disregard the effect of traffic as well as many significant environmental parameters. Actual traffic tests are inadequately controlled, meteorological conditions vary widely, and the volume of traffic is not directly related to clearance rate of the entire pavement because of the tendency for traffic to be channeled. A further drawback in conducting tests on a public highway is the hazard posed to motorists when less then optimum procedures for control of snow and ice are used to determine the optimum. This has led to the concept of a traffic test track.

Proposed Research

1. Conduct a 2- or 3-year test program, using a circular outdoor pavement test installation located in a region of heavy and frequent snowfall so that tests can be conducted under natural snow and ice conditions or under artificially induced icing.
2. Establish effective pavement anti-icing techniques by using minimum quantities of chemicals under a wide measured range of environmental, traffic, and pavement conditions.

Maintenance Operations

1 Traffic Control at Hazardous Locations

Problem Statement

Frequently traffic control measures at maintenance work sites have been based on subjective assessments and not on objective data regarding the effect of the measures on either traffic flow behavior or motorist safety. The development of traffic control plans should be based on objective criteria, and uniform standards should be applied across the United States.

Proposed Research

Establish objective criteria and develop a manual for use by highway workers in producing an effective system to alert and guide vehicular traffic through hazardous portions of highway projects.

2 Safety Line Application

Problem Statement

The mobility of a pavement marking operation makes it difficult to adequately warn approaching motorists. A related problem is failure of motorists to take appropriate evasive action.

Proposed Research

1. Investigate and evaluate existing warning devices for pavement marking applications.
2. Determine the optimum warning to alert approaching motorists.
3. Recommend improved warning devices to provide adequate warning to approaching traffic.
4. Determine the safety advantages and disadvantages of nighttime striping.

3 Sign Maintenance

Problem Statement

Sign maintenance personnel have a need for criteria or instruments or both to determine when a sign has reached the end of its effective life and should be replaced.

Proposed Research

Develop criteria and instruments to assist sign maintenance personnel in their decisions on whether to replace a sign.

4 Handling Traffic During Bridge Maintenance

Problem Statement

When major maintenance is performed on bridge decks, the bridge may have to be closed, particularly in urban areas, and traffic routed over an alternate route. However, consideration of the costs of added travel and lost work time for the rerouted drivers and passengers may make it more cost effective to incur additional maintenance cost and carry the traffic through the work site. All relevant factors are not currently considered in the decision-making process. Some of these factors include traffic volumes, length of time maintenance will be conducted, potential hazard to traffic, potential hazard to work forces, cost of time and travel to motoring public, percentage of commercial traffic, ability to periodically open and close work site, and unit cost of maintenance under traffic and nontraffic conditions.

Proposed Research

Define relevant, tangible cost factors in deciding whether traffic should be carried through a major maintenance bridge deck work site or detoured around it.

5 Traffic Accidents at Highway Construction Work Sites

Problem Statement

There is little evidence on whether special accident problems at highway construction work sites are substantially different from those at other highway locations. Separate records are seldom kept of accidents occurring at or near such sites.

Proposed Research

1. Assemble and study accident information to establish the extent and the nature of the hazards at work sites.
2. Prepare recommendations for correcting the problems.

Transportation of Hazardous Materials

1 Standards for Safe and Damage-Free Commodity Transportation

Problem Statement

Those elements that are critical to the safe and damage-free movement of commodities by railroads, highways, air, water, and pipelines should be identified and standards defined for their numerical limits for packaging, handling, and movement. Minimum standards would eliminate unnecessary care, handling, and packing for shipments by the required transportation media. Some work has been done on identification of critical transportation environments and on assignment of factors to reflect shipping risks. However, additional research is required to refine these and to develop more realistic limits to reflect more accurate standards for the hazardous and fragile commodities that are to be transported.

Proposed Research

1. Survey and review current criteria being used for transporting commodities.
2. Recommend definitive standards for safe and damage-free transportation of commodities by the various modes of transportation.

2 Effects of Risks in Highway Accidents on the Design of Hazardous Materials Containers

Problem Statement

Despite the occurrence of many thousands of accidents involving freight vehicles on U.S. highways, practically no data are available to define the engineering and risk considerations that should be incorporated into hazardous materials packaging or container designs to accommodate accidents. Thus, the crash behavior of the containers and packagings of these hazardous materials and the effects of this behavior on risk cannot be identified or controlled with confidence. The present hazardous materials accident reporting system required under 49 CFR 171.16 does not call for such data. In the absence of these data, the identification and control of risks attributable to the packaging of hazardous materials involved in highway crashes cannot be successfully achieved.

Proposed Research

1. Develop methods to acquire data in accidents.
2. Convert these data to estimates of engineering values such as the maximum or minimum decelerations, deflection forces, impact forces, force concentrations, package or container, and appurtenance.
3. Identify the effects of these design factors on the risk of injury that has been experienced in accidents.

3 Rehabilitation of Losses Resulting From Incidents Involving Hazardous Materials

Problem Statement

Personal injury and property damage resulting from incidents involving hazardous materials are now compensated for through a process of initiation of claims against parties who are alleged to have caused or permitted the accident to occur. Compensation is funded through hazard insurance or private resources or both of the causative entities. In a great many instances, claimants initiate damage suits in the courts in efforts to achieve compensation considered by them to be adequate. The legal process thus initiated requires an adjudication of fault as a prerequisite to liability. Social policy favoring deterrent or punitive damages or both is often a factor in the assessment of the amount to be awarded to successful claimants. The judicial process is costly, time consuming, and restricted in its evaluations by rules of evidence and procedure. Awards adjudicated often may be considered excessive or inadequate by parties involved and may be unobtainable where the party "at fault" is "judgment proof" because of lack of sufficient resources. Appellate procedures may prolong the time for final decision and impose further legal costs. Many claimants are dependent on the availability of counsel willing to represent them on a contingency fee basis. Defendants often feel constrained to limit their participation in the search for factual causation because of the evidentiary value of any such efforts on their part. The legal protection afforded by strict compliance with regulatory standards tends to dissuade independent initiative that promises to further reduce risks. Regardless of the final outcome, major accidents subjected to determinations of legal liability lend credence, because of the time involved, to the premise that "justice delayed is justice denied." Furthermore, justice in many instances turns on the credibility and effectiveness of the competing expert witnesses testifying at trial, while the judicial process itself may restrict the potential value of expert analysis with respect to the case at hand and with respect to preventive or mitigating considerations for the future.

Proposed Research

1. Explore the potentials available for separating the process of rehabilitation from the process of fault determination in order to achieve a capacity to provide responsive rehabilitation in terms of type, quantity, and time; to ensure adequate funds; to reduce costs to complainants; to establish a sound distinction between "responsibility" and "fault"; to achieve maximum benefit from expert analysis of causation; and to impose a specific obligation for retribution only where and to the extent that it is fair and in the public interest to do so.
2. Include a factual analysis of selected accidents that have occurred in the past and resulted in final settlements and evaluate the adequacy of existing claims settlement processes.
3. Recommend change, where and if found desirable, and propose legislation and processes for implementing the proposed recommendations.

Highway Capacity and Quality of Service*

1 Computing Intersection Approach Capacity

Problem Statement

Figure 6.3 of the 1965 Highway Capacity Manual shows the effect of the number of lanes and various approach widths on intersection approach capacity. The text indicates that this figure is not to be used in capacity determinations, but is used only to indicate how best to operate a given pavement width to ensure attainment of computed capacity. More recent data indicate that the number of lanes, possibly in combination with lane widths, may be appropriate for capacity calculations. Some evidence indicates that the most appropriate method varies depending on what level of service is involved, i.e., at capacity a 10-ft (3-m) lane may do as well as a 12-ft (3.7-m) lane, but this may not be so at level of service C. Capacity calculation techniques in other countries use measures of pavement width other than the total approach width measured in feet (meters), and studies are warranted in this country to determine whether the number of approach lanes, the width of the approach, or the width of the individual lanes should be used for this purpose.

Proposed Research

1. Conduct field work to evaluate the effect on capacity and service volume of changing the number of traffic lanes painted on intersection approaches.
2. Concentrate the data gathering effort on odd-width approaches, i.e., those that do not provide even multiples of 11- or 12-ft (3.4- or 3.7-m) lanes, so that the initial data gathering effort can be minimized.
3. Gather data on intersection approach width, number of lanes, individual lane widths, entering traffic volumes by signal phase by lane, and such other traffic flow data, including loaded cycles, total delay, and starting time delay, as might be valuable as part of a future comprehensive study of intersection approach capacities.
4. Because many variables, such as driver performance, cannot be measured or controlled, restrict data gathering to a limited number of intersections with a variety of pavement marking systems [for example, a 27-ft (18-m) approach could be marked and data gathered under the configurations of no lane designation, marked as 2 lanes, marked as 3 lanes, or marked as 2 lanes plus opposing left-turn lanes].

2 Effects of Left Turns on Capacity at Two-Phase Signalized Intersections

Problem Statement

Capacity of intersections controlled by 2-phase traffic signals is adversely affected by left-turning vehicles, especially when the opposing traffic volume is high. Reduction factors for left turns, as given in the Highway Capacity Manual for the basic case of no separate left-turning lanes or signals, do not at present reflect the effects of different levels of opposing traffic volume. In addition, more study is needed of effects of number of moving lanes (or approach width) on left-turn adjustment factors as now given in Table 6.5 of the manual. Other potential factors include presence of a left-turn storage lane, prohibition of parking and standing in the approach, cycle length, actuated versus pretimed control, width of exit roadways, and turning radius.

Proposed Research

1. Conduct field work and computer simulation studies to evaluate effects of opposing flows on left-turn reduction factors at pretimed 2-phase signalized urban intersection approaches, considering some or all of the following variables: low, medium, and high opposing flows; zero, low, medium, and high (more than 10 percent) left turns; no parking versus parking, versus prohibiting parking 50 to 150 ft (15 to 45 m); and 1, 2, or 3 moving lanes (some with a median left-turn lane).
2. If possible, use a limited number of intersections, and vary some conditions by temporarily changing signal timing, prohibiting parking, prohibiting turns, removing turn restrictions, shifting centerline, perhaps using test drivers to add left-turning or opposing vehicles to the traffic streams, and in some cases using pairs of intersections on the same street.
3. Use time-lapse photography to record performance by lane for left-turn, through, and right-turn movements (both approaching and opposing), entry headways, phase length, vehicle classification, parking conditions, use of bus stops, length of queue, and loaded cycles.
4. Use these data to compute left-turn reduction factors and to calibrate computer simulation runs for evaluating left-turn reduction factors for different sets of conditions.

3 Relation of Load Factor and Delay

Problem Statement

The 1965 Highway Capacity Manual proposes that load factor be used as the measure of level of service at signalized intersections. Load factor is defined as "a ratio of the total number of green signal intervals that are fully utilized by traffic during the peak hour to the total number of green intervals for that approach during the same period." An understanding of load factor is of particular concern because of the importance of the concept of level of service in the manual and because of its obvious effect on selecting service volumes for capacity analysis. The use of load factor as a measure of level of service in lieu of estimation of delay at an intersection was born of the lack of data and difficulty of delay measurement. It was also based on the feeling that load factor provides a simple concept for application to generally reflect a level of congestion in a readily quantifiable manner. Experience has indicated that load factor is most useful in application to operational analyses of existing intersections. It has limited value as a description of congestion in planning and design because decision makers have more difficulty relating to it than to delay per vehicle. Research is needed to provide a relation between delay, load factor, and level of service. A further development of the concept of level of service is needed as it relates to an overall intersection or the system as a whole. A further development of the concept of load factor is also needed as it relates to each lane and in a combined measure of an approach or intersection.

Proposed Research

1. Determine the usefulness of the delay, load factor, and level-of-service concepts from practice in the areas of operation, planning, and design.
2. Explore alternative measures of level of service and consider the potential application in computerized signal systems and road user benefit analyses and the more

common application in establishing level of service and service volumes.

3. Address the level of accuracy required for each potential application.
4. Collect field data on load factor and delay at a number of intersections that represent the variety of configurations, upstream conditions, cycle length, and offsets that exist and also on variables required in the saturation flow method of intersection analysis used in Great Britain.
5. Conduct intersection simulation studies of the more straightforward types of intersections (e.g., each approach on a separate phase) as a supplement to, and in comparison with, the field data on delay and load factor.
6. Concurrently with the 2 preceding steps, make a preliminary revision of the definition of level of service at intersections in order to develop a delay criterion based on a correlation with the volume-capacity ratio so that a set of delay values may be defined relative to the various levels of service and translated to corresponding volume-capacity ratios for a given condition (thus the present concept of level of service may be retained and refined, but directly related to delay unless a more desirable measure is developed as part of the earlier described work).
7. Develop a methodology for the estimation of intersection delay per vehicle for use in road user benefit analysis.

4 Overall Urban Arterial Capacity and Levels of Service

Problem Statement

No significant criteria for capacities and service volumes exist for extended sections of urban arterials and streets comparable to those that have long existed for various types of rural highways. The 1965 Highway Capacity Manual, recognizing this deficiency, suggests as a stop-gap method an intersection-by-intersection analysis supplemented by judgment in analyzing obvious nonintersection bottlenecks that may govern flow. Effective application of the level-of-service concept to urban arterials and streets requires establishing better "over-a-distance" capacity and service volume criteria and incorporating midblock performance in addition to intersections.

Proposed Research

1. Determine and evaluate past work that may have been done in this area.
2. Evaluate traffic performance on typical urban highways to establish conditions under which features other than intersection operations may govern capacity.
3. Develop specific criteria for capacities and service volumes of such nonintersection features.
4. Develop, if feasible, simplified overall capacity and service volume computation procedures for extended sections of urban arterials and streets.

5 Influence of Signal Timing and Phasing on Intersection Capacity

Problem Statement

Signal timing is probably the single most important controllable factor in the operation

of a signalized intersection. The Highway Capacity Manual recognized this importance, but contained only a general discussion because of the lack of detailed research results. In practice, the design of a signalized intersection and its corresponding timing and phasing elements must consider both the physical and the demand characteristics of the intersection. Design details must include phasing, phase sequencing, intervals, interval duration, cycle length, signal coordination, and the type of operation, i.e., fixed-time versus actuated control. The present techniques contained in the manual are strongly related to the individual intersection approach. These procedures are easily applied to the simple intersection. The pressures in many growing areas, however, call for more complex operation including multiphases, overlapping phases, skip phasing, and other timing elements that are not adequately covered in present capacity calculation techniques. These elements should be examined from the capacity standpoint to develop guidelines to aid the user in developing appropriate signal timing and phasing schemes at the individual intersection.

Proposed Research

1. Examine factors, including those that follow, that directly contribute to the operation and capacity of multiphase signal installations: (a) operational- and capacity-related effects of alternate phase relations and sequencing strategies; (b) qualitative effect of cycle length alterations on capacity with and without split variation; (c) capacity value impact associated with random arrival versus platooned arrival; and (d) effect on capacity of nonloaded yet required phases at multiphase intersections, e.g., pedestrian phases and special clearance phases.
2. Identify and categorize the primary configurations.
3. Make theoretical evaluations to describe the potential capacity conditions under various forms of loading.
4. Validate these theoretical capacity calculations through field measurements at selected locations meeting the configurations set forth.

6 Capacity of Separate Turning Lanes and Phases

Problem Statement

The number of vehicles that can execute a left turn or a right turn at a signalized intersection that has separate lanes and a protected phase depends on a number of primary factors: (a) starting time delay of the vehicles in the queue that begin to move after the signal indication changes to green, (b) headway characteristics of each vehicle in the queue, (c) cycle length, (d) length of the queue and its effect on headway characteristics of the individual vehicles in the queue, and (e) cycle-by-cycle arrival rates during the peak traffic period. Secondary factors may include (a) driver aggressiveness, which may be measured by metropolitan area population and location within the metropolitan area; (b) physical and geometric features; and (c) traffic characteristics, such as the number of trucks and buses. Another consideration is the length of the right- or left-turn lane to be provided depending on the input-output characteristics of the turning vehicle stream and the cycle length-green phase time provided. The length of the adjacent through-traffic queue must be considered to ensure that access to the turn lane is not blocked. Extremely limited research was used to develop the procedures and factors contained in the Highway Capacity Manual.

Proposed Research

1. Conduct field studies at selected intersections to determine the traffic flow characteristics of separate turning lanes with exclusive signal indications.
2. If possible, use a limited number of intersections at various locations throughout the country as a means to evaluate driver aggressiveness as related to population size, section of the country, or pressure of driving conditions.
3. Use time-lapse photography or videotape to record performance to ensure compatibility of measurements at different intersections and locations throughout the country.
4. Record several hours of performance during peak flow periods and vary cycle length and phase length of traffic signal control to produce a wide range of queue length situations (this type of recording allows the reviewers to selectively evaluate data to determine the significant variables).

7 Overall Intersection Capacity

Problem Statement

Planners and administrators have knowledge of the mobility requirements or demand of their constituency. This demand is the design load for traffic facilities and is an overall factor without regard for direction of flow. However, the facility governing traffic flow is the road intersection, and the administrator should know its overall capacity in order to plan properly. Heretofore the Highway Capacity Manual has been concerned with capacity of approaches to the intersection. There is now need to look into the capacity of the intersection as a whole.

Proposed Research

1. Make a literature search to determine accomplishments to date.
2. Formulate a mathematical model for determining intersection capacity.
3. Select a set of intersections for study that is representative of factors shown in Figure 6.1 of the Highway Capacity Manual.
4. On all approaches under varying conditions of traffic controls, measure traffic flow properties including but not limited to volume, classification, density, approach speed, delay in queue (before and after green) by lane and by signal cycle, and amount of unused green time.
5. Vary traffic controls at certain intersections to determine effect of movements such as turning and parking on traffic flow and also vary cycle lengths and splits to determine signal timing effect on capacity.
6. Compute intersection capacity as the amount of traffic that may pass through the intersection, from all approaches, under varying properties of flow and control measures.

8 Effect of Parking on Intersection Capacity

Problem Statement

Parking is one of the physical and operating conditions that tend to restrict the capacity of a roadway intersection. Generally, such a reduction is caused by loss of

approach width due to a parking lane, parking or unparking maneuvers, driver response time in viewing parking and unparking maneuvers, or a combination of these factors. The Highway Capacity Manual states that, if parking is allowed within 250 ft (75 m) of an intersection, the intersection capacity should be determined under the "with-parking" condition. But, no explanation of this rule of thumb is provided.

Proposed Research

1. Evaluate the effect of parking on traffic delays and subsequent capacity reduction of an intersection to obtain statistically correlated principal variables such as street width loss, parking maneuver characteristics, parking distance from the intersection, presence of drivers in the street, traffic volume, and signal timing and determine which one or which combination most logically represents effectiveness over broad ranges of traffic and intersection conditions.
2. Conduct a state-of-the-art study to synthesize the current concepts.
3. Obtain by canvass the criteria and current practices in roadway design and traffic control in relation to intersection parking.
4. Establish a definite relation between parking and intersection capacity in terms of degree of detail, realism, and simplicity of application.

9 Effect of Pedestrians on Intersection Capacity

Problem Statement

Of the many factors influencing intersection capacity, the effect of pedestrians is one that has not been adequately quantified. The 1965 Highway Capacity Manual only mentions pedestrian influence and has no adequate data or technique for modifying the capacity of an intersection. In urban areas, particularly in central business districts, pedestrians must share intersections with vehicles and thus reduce the vehicle capacity. To optimize all transportation requires that delay be minimized to both vehicles and pedestrians alike. Pedestrian movement, environment, and safety have become increasingly important in urban area planning. As a first step in understanding the vehicle-pedestrian conflict and relation, the effect on vehicle intersection capacity by pedestrians must be determined.

Proposed Research

1. Conduct a survey of material, studies, and research in this area to provide the base from which to begin the research.
2. Collect specific data at selected intersections to adequately determine the influence of principal variables, including pedestrian volume, vehicle volume and turning movements, street width, and signal control.
3. Establish the relation between pedestrian volume and intersection capacity for different types of areas, types of facilities, and intersection configurations.
4. Develop a model and test and calibrate it for selected locations with appropriate variety of conditions for the possible cases noted.
5. Establish a procedure and guidelines for determining signal phasing for maximum intersection capacity for vehicles and pedestrians.

10 Saturation Flow as a Basis for Determining Intersection Capacity

Problem Statement

Current U.S. practice in determining intersection capacities could likely be improved if saturation flow were adopted as the basis for intersection capacity computations. Since this approach, which is practiced in Britain, Australia, and some other countries, is not much different in basic concept from the approach in the Highway Capacity Manual, the improvements, if any, would most likely come from technical and practical grounds. If results of the evaluations indicate that the saturation flow approach offers considerable technical and practical merits over the current approach in the manual, the problem then will become one of obtaining the U.S. saturation flow values so that the approach can be exercised.

Proposed Research

1. Establish whether the saturation flow approach has considerable technical and practical merits over the approach in chapter 6 of the 1965 Highway Capacity Manual.
2. If the result of this evaluation is positive, study and evaluate the various methods in this country and in other countries of obtaining saturation flow values and identify the most effective method in terms of its practicality and quantitative interpretation of the definition of saturation flow, base condition, and measuring techniques and units.
3. Based on the method selected, determine whether existing quantitative saturation flow values are available and applicable.
4. If existing values cannot be obtained, determine whether existing data are adequate and can be used to obtain saturation flow values for U.S. purposes or identify the data needs for such a purpose.

11 Delay as a Quality of Service Criterion for Intersection Performance

Problem Statement

Delay is considered to be an important element in evaluating traffic performance at individual intersections. The TRB Committee on Highway Capacity is considering using delay as a criterion for level of service at signalized intersections. Delay also is specified as a warrant for 4-way stop control in the U.S. Manual on Uniform Traffic Control Devices. However, as yet, there are no standard methods for measuring delay and for using results in defining quality of service. In addition, network effects also need analysis to evaluate effects of upstream and downstream signals and offsets on delay at individual intersections.

Proposed Research

1. Evaluate field methods for measuring delay to arrive at standard field methods for measuring stopped-time delay and aggregate delay and to identify relations between results of the 2 methods.
2. Examine possibilities of using average queue length (average of maximum queue per cycle).
3. Select a limited number of "saturated" signalized intersection approaches and use sampling and aggregate methods and time-lapse photography for field measurement of delay for off-peak and peak periods.

4. Use data from films for calibrating the UTCS-1 simulation program and for identifying loaded cycles.
5. Compute correlations between methods for measuring delays and check via UTCS-1 computer simulation.
6. Review all possible delay criteria for quality of service for signalized intersections and identify possible standards for using delay instead of load factor as a measure of level of service.
7. Examine criteria for 2-way stop control and determine how delay might be used as a factor in warrants for signal installation.

12 Passenger Car Equivalents in Intersection Capacity Computations

Problem Statement

Methods for computing signalized intersection capacity and service volumes, as developed in England and Australia, use effects of left and right turns and commercial vehicles in terms of passenger-car equivalents for through movements. For U.S. conditions few data exist for use in examining applicability of British and Australian methods.

Proposed Research

1. Examine library materials related to the subject.
2. Conduct field studies to evaluate effects on starting delays, lane headways, and loaded-cycle output (saturation flow) of commercial vehicles, right turns, left turns, grades, and parking in the curb lane (opposing flow is measured as part of the study of left-turn equivalents).
3. Use time-lapse photography to record performance at a limited number of intersection approaches that have 2 to 3 moving lanes, no separate turning lanes, and 2-phase control.
4. Use data obtained from the films in computing passenger-car equivalents and also for calibrating computer simulation models.

Traffic Flow Theory and Characteristics

1 Effects of Horizontal Alignment on Freeway Traffic Characteristics

Problem Statement

A variation in horizontal alignment may significantly affect not only traffic safety but also traffic flow. More needs to be known about the basic relations between alignment and traffic performance.

Proposed Research

1. Determine the individual and joint effects of curvature on freeway traffic flow characteristics.
2. Obtain traffic flow, speed, and headway information at several locations presenting realistic combinations of alignment characteristics.

2 Impact of Traffic on the Environment

Problem Statement

The impact of traffic on the environment is a problem with which highway engineers must cope every time a roadway is located, designed, or reconstructed. Relatively little information is available relating noise and air pollution and other environmental factors to traffic flow characteristics. A knowledge of these relations will enable the operating engineer to minimize adverse environmental impacts.

Proposed Research

Define the relations between traffic flow and environmental quality characteristics.

3 Effect of Unwarranted Traffic Control Installations

Problem Statement

As a result of political pressure, traffic control devices are sometimes installed at locations where they are not needed. Traffic authorities often do not have adequate information to prevent these installations. Research is needed to develop information on undesirable traffic flow characteristics resulting from unwarranted traffic control device installations.

Proposed Research

1. Locate unwarranted traffic control installations.
2. Conduct studies at these locations to determine their effects on traffic flow.

4 Effects of Incidents on Controlled-Access Facilities

Problem Statement

Although controlled-access facilities are designed to carry large volumes of traffic based on theoretical and empirical capacity standards, too often a traffic incident substantially reduces capacity on the freeway even when a lane is not blocked. Research is needed to quantify the effect various types of traffic incidents have on various levels of traffic flows.

Proposed Research

1. Measure and record various traffic flow parameters including incident type, duration, volumes passing the incident, and resulting queue development related to each specific type of traffic-capacity-reducing incident.
2. Develop models to predict the effects of various types of incidents on freeway traffic flows and institute systems to minimize the effects of these incidents on motorists.

5 Reestablishing Stability of Traffic Flow Beyond a Conflict Point

Problem Statement

The uniformity of flow of a stream of traffic is frequently disturbed by vehicles leaving or entering the freeway, and adjustments must be made by drivers to adjust the speed and spacing of their vehicles to the changed condition. The distance required to establish uniformity of flow downstream of a point of conflict needs to be determined because during this period of instability a multitude of decisions are made by the driver. If additional points of conflict are introduced within the distance of stabilization of flow, the driver's ability to make the proper adjustments may be overtaxed, leading to a greater chance of driver error and accidents. Spacing of ramp termini, lane drop-offs, or geometric features necessitating driver decision should be spaced at least at distances great enough to permit reestablishment of uniformity of stream flow.

Proposed Research

1. Determine features that describe uniformity of flow, such as spacing, speed, and any additional time required by the driver entering the freeway to adjust to the changed environment.
2. Develop a model for determining the distance downstream of a point of conflict at which stability and uniformity of traffic flow are reestablished.

6 Determination of Freeway Section Safety in Terms of Traffic Characteristics

Problem Statement

On many different sections of freeways, vehicles show erratic flow behavior including excessive lane changing and accepting relatively short gaps. This erratic behavior is

due to the presence of different types of geometric conditions on freeways and to the complex traffic maneuvers resulting from several drivers entering and leaving the freeway in that area. For these reasons, certain freeway sections have reduced capacity and are also considered to be dangerous. There is no systematic procedure to evaluate these sections in terms of safety, driver comfort, and normal traffic behavior.

Proposed Research

1. Compare behavior on these freeway sections with normal gap acceptance, gap stability, and lane-changing behavior on straight, uniform sections of freeway with no nearby on- or off-ramps or other geometric conditions.
2. Make similar evaluations for known dangerous areas that have high accident statistics and relate these statistics to the deviation of the abnormal gap acceptance, gap stability, and lane-changing behavior from the normal behavior on the straight section of freeway (other freeway sites can be tested out in a similar manner so that dangerous sites can be corrected by appropriate physical or operational improvements).

7 Driver Information Processing

Problem Statement

What information helps a driver? What information merely distracts a driver? For better design of signs, signals, markings, lane geometrics, and other driving aids, a comprehensive description is needed of the manner in which a driver receives and processes information. The description must consider (a) limitations on the driver's information gathering capabilities as a function of environment, speed, motivation, and other factors; (b) conflicts between the driver's information gathering and information processing functions; and (c) factors influencing the driver's processing abilities such as motivation, fatigue, and vehicle characteristics. The description should incorporate knowledge from all pertinent scientific disciplines, including experimental psychology, information theory, and systems engineering. When completed, the research should enable the tracing of quantitative relations that will determine matters such as (a) how inadequate information affects driver reactions and reaction times; (b) how much information per time interval a driver can use effectively; (c) how important information about relative velocity is and how this importance varies with time and distance spacing; and (d) what the relation is between driver motivation and driver reaction times. Furthermore, the research will provide the foundation for design of a driving simulator capable of generating and reproducing a variety of controlled informational inputs.

Proposed Research

Prepare a precise description that relates all factors pertaining to the total driver-vehicle-road system and that is suitable as a framework for subsequent experimental studies aimed at determining quantitative relations among the various system elements.

Traffic Records

1 Continuing Evaluation of Accident Report Coverage

Problem Statement

Policies and procedures of the Federal Highway Administration require or encourage the development of safety improvement programs, the use of accident data for identifying hazardous locations, and the accurate reporting of accidents and locations. Limited data available, however, indicate that little is known about the coverage of accidents by reports or the accuracy of locations.

Proposed Research

1. Conduct a pilot study to determine what is now happening with respect to coverage and accuracy and conduct sampling studies in several agencies.
2. Develop and test a model for continuing sampling analyses to provide essential knowledge for any agency using accident data analyses as a basis for highway safety improvement programs.
3. Recommend procedures for incorporating model sampling procedures in an overall safety management system.

2 Exposure Measure for Rate Calculations of Motor Vehicle Traffic Accidents

Problem Statement

The need for consideration of the exposure to accident has long been recognized as valid in evaluating traffic accident data. As the overall problem grows, however, and as the complexities of both the problem and possible countermeasures increase, simple exposure measures fail to produce significant identification and evaluation of problems and solutions.

Proposed Research

1. Define possible exposure parameters for vehicles, drivers, pedestrians, highways, and other safety-related features.
2. Determine logical combinations of parameters related to highway safety standard elements and subelements.
3. Test the feasibility of using defined exposure measurement parameters as part of state and local safety management reporting systems.
4. Recommend future needs for traffic records related to exposure measurement.

3 Evaluating and Reporting Losses in Motor Vehicle Traffic Accidents

Problem Statement

In measuring accident experience, 2 yardsticks may be employed: one based on frequency of occurrence and one based on severity or extent of loss. For half a century, essentially the same crude description has been used to evaluate the harm or loss of a motor vehicle accident: the accident is categorized as fatal, injury, or noninjury.

Thus, as far as input to the records system is concerned, an accident in which an elderly pedestrian is killed is as bad as a school bus collision killing 5 children, and a scraped fender on an old car is as serious as a tractor and trailer that overturn and burn with no injury to the driver but with a $50,000 property loss. Specific information on fire losses, for instance, needs to be related meaningfully to overall experience.

Proposed Research

1. Analyze existing severity scales to determine strengths and weaknesses.
2. On a conceptual basis, devise a scale or index that will combine individual elements of loss to indicate the real severity of the collision.
3. Calibrate the scale through controlled crash tests or other means.
4. Test the concept for field usefulness and managerial acceptance.

Effectiveness of Operational Measures

1 Rapid Safety Performance Measures for Highway Improvements

Problem Statement

The evaluation of highway operational improvements from a safety standpoint requires the accumulation and compilation of accidents before and after the alleged improvement. To ensure sufficient traffic exposure to the highway change so that conclusions can be rendered regarding effectiveness often requires the passage of a considerable amount of time after the improvement is made. Measures are critically needed that are highly correlated with highway accidents to permit evaluation of improvements without waiting for accidents to happen.

Proposed Research

1. Define a set of candidate traffic performance measures that reflect the likelihood of traffic accidents on a section of highway or at a spot location.
2. Collect data on each of the measures on a variety of roadway types.
3. Procure accident frequency and severity data on the same sections of roadway (and spot locations) where traffic performance information is gathered.
4. Analyze the correspondence between the traffic performance measures and the accident data and identify the measures that best reflect the safety performance.
5. Develop guidelines for use in quickly and simply assessing quantitatively the safety effectiveness of roadway improvements.

2 Measuring the Level of Service on Urban Arterial Streets

Problem Statement

The level-of-service concept in the 1965 Highway Capacity Manual is being used with increasing frequency in analyzing the capacity limitations of sections of arterial streets. The 1965 manual does not include any "typical" speed-volume curve for urban arterials similar to that determined for rural highways. Neither can any single speed and volume-capacity ratio curve, or group of curves, represent urban arterial operations. The levels of service on arterial streets are determined by using the criteria of overall travel speed and the volume-capacity ratio. This involves detection and analysis of operating levels of all potential restrictions and overall analysis of the artery. In practice, it is normal to ignore midblock capacity restrictions unless they are abnormally severe and to analyze only the important intersections. A method is needed for evaluating the level of service at which an arterial is operating without having to go through the laborious calculations recommended in the 1965 Highway Capacity Manual.

Proposed Research

1. Identify measures of effectiveness that are useful in describing levels of transportation service on urban arterial streets.
2. Quantify levels of transportation service on urban arterial streets.
3. Develop and validate practical methods for simply and quickly determining the levels of service on urban arterial streets.

3 Determining Levels of Transportation Service in Urban Freeway Corridors

Problem Statement

Improving the level of transportation service in urban freeway corridors is receiving considerable emphasis. Several large systems using advanced techniques are being implemented, and several spot improvements are being made. In line with corridor operations, before-and-after analyses are generally conducted to illustrate improvements. Most of the improvements have been reported in terms of the increase of vehicle movements and reduction in delays within the corridors. Little emphasis in the past has been devoted to passenger and goods movement. In addition, there is still uncertainty as to what constitutes good service. To evaluate the facilities (freeways, frontage roads, and arterial streets) as individual components is common practice. No unified approach ties these facilities into one system so that the level of service of the total corridor can be determined.

Proposed Research

1. Identify measures of effectiveness that are useful in determining corridor levels of transportation service.
2. Quantify levels of transportation service within urban freeway corridors.
3. Identify acceptable levels of transportation service during peak and off-peak periods.

4 Comparing Accident Data for Highway Sections and Spot Locations

Problem Statement

Traffic accident data are usually expressed as accidents (of several categories either individually or totally) per 100 million vehicle miles (160 million vehicle kilometers) for sections of highway, per million entering vehicles for intersections, and sometimes per mile for nonintersection spot locations. A technique is needed to make comparisons among accident data for highway sections, intersections, and spot locations for the determination of priority rankings, resource allocations, improvement programs development, and other purposes.

Proposed Research

1. Identify common exposure bases or relate existing bases by an easily used comparison factor.
2. Develop matrices, nomograms, or other graphic means of displaying such accident data.
3. Develop a means of evaluating and comparing accident experiences at different types of locations.

5 Effect of Road Improvements on Traffic Operations

Problem Statement

Measurement techniques, criteria, and guidelines are needed to aid highway and traffic engineers in determining both the benefits of upgrading highway facilities or spot locations and the potential disbenefits to adjacent highway sections. Standardized methodology is needed for determining the effectiveness of road improvements on traffic operations and to aid highway and traffic engineers in assessing not only the effectiveness of such improvements at the location where the improvement was introduced but also the impact on adjacent highway sections.

Proposed Research

1. Define a set of candidate traffic parameters to measure the effectiveness of improvements such as road and shoulder widening, realignment, access control, and additional lanes.
2. Develop analytical or empirical techniques to determine the potential adjacent areas that might be affected by a particular road improvement.
3. Identify the traffic parameters, including the types of measures, methods of measurement, and minimum sampling requirements, to measure the effectiveness both at the improvement location and adjacent areas.
4. Develop models or traffic engineering guidelines to predict the impact of a road improvement at the immediate and the adjacent highway areas.

6 Measures of Speed Variation

Problem Statement

The speed of traffic has been studied for years through spot speed and travel speed studies and by floating cars, which have provided measures such as spot speeds, travel speeds, speed changes, and acceleration noise. Unnecessary speed changes waste fuel, increase wear on the vehicle, and usually annoy the driver. Speed variations may also be related to accident rates, quality of service, and traffic flow characteristics. A standard measure of speed variation is needed.

Proposed Research

1. Define a set of candidate measures of speed variation.
2. Obtain actual speed trajectories on various types of roads and road environments and under various traffic conditions.
3. Simultaneous to obtaining speed trajectories, determine operational measures such as fuel waste, driver annoyance, traffic accident potential, and quality of service.
4. Determine the speed variation measures that are best correlated to the operational measures.
5. Determine the equipment and time requirements for measurement of the best speed variation measures.
6. Develop a plan for implementing the most appropriate measures.

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